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White Paper: Energy Storage

The Lithium and Hybrid-Electric Building Revolution

DRAFT -- February 23, 2016b -- DRAFT

This is a white paper on advanced energy storage and the role of lithium in the hybrid-electric building revolution. The paper documents the rise of battery-based storage systems for consumer, utility, and grid benefits. Comments, clarifications, and corrections are most welcome. This paper accompanies a slide-show presentation by Ted Flanigan titled, "The Lithium and Hybrid-Electric Building Revolution."

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1. Introduction: The Launch of Hybrid-Electric Buildings

It's hard not to be impressed by Susan Kennedy. She is energetic, powerful, and sharp as a tack. I pick her up at John Wayne Airport. We're both on time, actually two minutes late for separate reasons. I haven't seen her in eight years despite Wally McGuire's suggestion to each of us. But for the past few months, we've exchanged few calls. What she's got going at Advanced Microgrid Solutions is really exciting.

We met years ago in a PG&E board meeting. She was a brand new California Public Utilities Commission (CPUC) commissioner, a change agent; I was Managing Director of The Energy Coalition. We reminisce and drive to 20 Pacifica, the site of the hybrid-electric building kick-off. It's her event; we're early on purpose. We hit a Spectrum Starbucks, upstairs at Barnes and Noble, with time to swap insights on storage. Hers are far more prescient than mine.

It's a lively conversation. Susan's vision is to effectively integrate renewables and storage into microgrids, to find multiple benefits from systems. The benefits can flow to both consumers and utilities and to the grid. She explains that it's about finding synergies. She talks voltage regulation, demand response, and even negative capacity. In my estimation, hers is a superior business model.

The new complexion of the power market will change, from centralized grids to microgrids. And contrary to logic, microgrids will be enhanced by by heightened levels of interconnectivity. They can serve grid functions, for a profit. Such new utility formations are shaping the electric utility industry. It's not about big, centralized power plants anymore. It's about a network, all connected, and able to "island" when need be. These islands, or microgrids, are enabled by storage. And storage is now being enabled big time by lithium.

Susan's balance of intensity and quiet, calm demeanor impresses me. She's the biggest purchaser of Tesla batteries – signing a $200 million contract that includes a declining unit cost structure. After talking shop for an hour, and on route to the kick-off event, I ask her about her life and her pace. She talks of being Schwarzenegger's chief of staff… the demands of that job. Now it's different. This is a different demanding. She's running AMS and is running hard in a new, dynamic market – driven by lithium.

The 20 Pacifica Kick-Off

Sun shining and there's a buzz in the air. We gather at 20 Pacifica in Irvine. This office complex is spit polished, a Sim City reality. You could have a picnic in the parking garage. I know the place for two reasons: EcoMotion put on an Option R Solar Forum there, and there's a choice café called Specialties that my bud Tyler likes. This office complex is one of many Irvine company buildings, formulaic and successful. I turn my cognitive set. Is this right? In this modern, unassuming spot, a building movement is born? This is the site of the first hybrid-electric building in a fleet.

We park in the garage and are directed down a path to the battery bank site. It will be screened off later, but now is prominent. A crane has been lifting white shimmering battery banks onto a newly poured concrete pad. Ultimately this impressive bank of some 16 Tesla batteries will be connected to a 250 kW inverter. The system can hold a 1,500 kWh charge, thus it can deliver 250 kW of capacity for up to six hours… matching Southern California Edison's six-hour summer peak demand period. And since they are lithium-ion batteries, they can do so day in and day out for many years to come. The deal is for ten years, all third-party financed and with a performance guarantee.

The ceremony kicks off "the hybrid-electric building" revolution. There's a short ceremony… speeches. Susan Kennedy is front and center. She's the architect of this plan and welcomes the 60+ in attendance. The Irvine Company is lauded for its forward thinking. Lots of photos taken, later staged. The media is here. Next are reps from a financing firm (that finances firms like Google and Tesla, and now AMS), SCE, and the Irvine Company. These three firms are what Susan called "rock stars." I meet Jesse Bryson and swap cards. He's the SCE program manager for both the "LCR" and "PRP" solicitations. We'll get to those later.

The Irvine Company project involves 24 office buildings, reducing peak demand by an average of 25%, and 10 MW of dispatchable capacity for Southern California Edison when called. AMS partnered with SunEdison to finance and construct the projects. The system being installed as we watch, is doing double duty – serving the grid when called upon, and flattening each building's load profile concurrently. The batteries will be largely recharged at night – using low-cost off-peak power – and then discharged during peak periods to simultaneously lighten the load on the grid and power bill.

2. The Quest for Energy Storage

Energy storage is all the rage in the electric utility world, in the spotlight with LEDs. Storage has come of age… touted as “advanced energy storage.” That’s a bold claim. Today’s “advanced technologies” for storage may remind us of beta-maxes in time. But don’t let me dampen the enthusiasm: Storage is now sexy in the power world!

In fact, 2015 was a banner year for storage. GTM Research projected that annual storage capacity addition in the United States was 192 MW, triple last year’s total. The report went on to site the PJM market as “dominating the market” with storage for frequency regulation, with utility-scale developments in Vermont and Georgia. Note that in the third quarter of 2015, 46 MW out of a total of 53 MW installed, were for utility-scale storage systems. (This report focuses primarily on “behind the meter,” consumer-hosted systems.)

This paper is all about the new, storage vernacular and how storage interacts with utility demand. It’s about predictive analysis; predicting peaks, learning algorithms, dynamic, fast-responding resources, intelligent storage; distributed storage (DS), and smart grid controllers. It’s about GreenStations, PowerPacks, and PowerWalls. We’ll link mobile and stationary energy storage solutions. It’s about “storage as a service,” and demand charge reduction strategies on steroids.

<u>Storage from Survival to Grid Solution</u>

But let’s back up… for say, thousands of years. Humankind has been storing energy throughout the course of civilization. Just as squirrels store nuts, we stack wood in the winter. We load up our fuel tanks with heating oil…. Some of us build houses so that sunshine heats a thermal mass that retains heat throughout the night. We insulate to store heat or coolth in our homes. These are all forms of storage. Some are chemical, others mechanical, and other thermal.

<u>Thermal energy storage</u>: There are many forms of thermal energy storage, some involving heat, others cooling. One Southern California based company – ICE Energy – has built refrigeration systems that use off peak electricity to make ice that then is used during the day to provide low-cost cooling, another form of storage. In Spain, EcoMotion witnessed solar systems tied with molten salts that can retain heat with minimal losses for days… storing energy that can later be used to generate power when its needed.

<u>Storing Power</u>

It’s easy to store oil in tanks and wood piles, but storing power is more challenging, its answer has been more elusive. It’s hard to store an electron cost-effectively. Household alkaline batteries store power, but at a cost of ~$140/kWh! That's an expensive form of storage: a chemical solution. So let's explore some other mechanical options.

Compressed Air: To fully capture the value of renewable resources, we need to store their output. Many wind farms generate most of their power at night, when it is not needed on the grid. Thus we now see compressed air storage systems offered with wind. Wind combined with compressed air storage has a levelized cost of electricity comparable to coal, but GHG emissions 1/10th of coal. It also raises the capacity factor from a wind turbine from 40% to 80%.

Supported by a $25 million USOE ARRA grant, PG&E has been testing the geologic suitability exploring and building a 300 MW Compressed Air Energy Storage (CAES) in San Joaquin County in the Central Valley. The system is being designed to provide 10-hour storage services. Similar storage facilities – that use depleted natural gas reserves – are in operation in Alabama and Germany and have been operating successful for a combined 50 years. Note that these are both in salt formations, not found in Northern California where porous formations are more common.

Flywheels: Flywheels are like potters' kick-wheels, they maintain momentum when the potter takes a break. Flywheel systems have been tested in subways to maintain momentum despite frequent stops. Enthusiasts of this form of storage point to the materials revolution that enables precision systems operating with minimal friction and at extraordinary revolutions per second.

Hydropower: The best power storage, one could easily argue, is hydropower. Massive quantities of water – measured in acre feet – are stored behind dams. The water is then released seasonally or to overcome peak demand periods on a daily basis. But dams are generally *damned*, so it's hard to imagine much new major hydropower. In fact, we may see less of this storage on a grand scale as these resources are often located in precious locations. Witness the ongoing fight over Hetch Hetchy in the Sierras.

Tidal: My favorite form of water storage it tidal, but these opportunities are rare. It's hard to imagine permitting a power plant in a tidal zone in America given environmental and recreational concerns. I wrote extensively about a South Korea tidal system that I visited some years ago. This impressive installation was enabled by a massive environmental pollution problem on site that made the effects of any flow of water back and forth environmentally inconsequential. For tidal storage, to value the latent energy in the water stored in a tidal system, you only have until the next tide to cash in!

Pumped Storage: Water storage is so good that utilities have built large two-lake systems for "pumped energy storage." Both utilities that I worked for – New York Power Authority and Los Angeles Department of Water and Power – have 1 GW pumped water systems. Effectively, a massive power plant can be turned on when you need it most. While inefficient from an energy standpoint (these systems are a net loss in terms of kWh), utilities pump water up at night using off-peak power, and then release during peak periods for financial gain.

The Solar Hydrogen Economy: When I was in grad school years ago, the energy future was not about batteries. They were absent from the conversation. Thankfully. I'd lived with battery banks in off-grid situations. Still remember the holes in my jeans made by the lead acid. Heck, Edison tried hard to increase the power density of batteries. But he was largely unsuccessful. And that's not to mention costs. Batteries have historically been messy, heavy, and expensive.

What was conceived was the Solar Hydrogen Economy. Bob Williams at Princeton was a huge advocate of this, and I bought in lock, stock, and barrel. This made sense to me: Using renewables we'd split water (electrolyze it) and use the hydrogen as a fuel. It can be burned, or run more efficiently through fuel cells. EcoMotion went to see this scenario in Iceland. Hydrogen can be piped and can also be safely stored in metal crystalline hydrates. Car companies, including Mercedes Benz were touting hydrogen as the next fuel for cars. So where did batteries come from? What warranted their resurgence? Lithium!

Enabling Off-Grid and Micro-Grid Solutions

There is great interest in microgrids. This is for several reasons. In some instances, microgrids are the only game in town. This is the "island model." EcoMotion Consultant Troy Strand has developed microgrids on islands in the Caribbean that combine gen-sets with solar and wind, and battery storage. Without these systems, there would be no power available. Without batteries, the full value of renewables would not be realized and there would be greater dependence on diesel fuel. These island instances – with no greater grid interconnection -- are known as states of "energy autarky."

Microgrids also provide for resiliency in the event that the grid goes down. Coop City in the Bronx was an electricity island during Hurricane Sandy. For hospitals, universities, and other institutions to be energy self-sufficient when need be, is enviable and oft critical. This we'll call the "resiliency model."

But as this white paper presents, microgrids also enable financial solutions for the vast majority of consumers that are a) not on an island, nor b) have paramount emergency back-up concerns. A new generation of microgrids enables smart energy management. They provide for both profits and hedges. They protect consumers from peak demand charges, and they protect consumers from peak energy use. To the greatest extent possible, like pumped storage facilities, they charge at night (off-peak), and discharge for profit in the day. This last form of microgrid is the "economic model." It is cost effective for consumers and investors. It involves energy efficiency, it involves distributed generation (DG), and now it is linked by "DS," distributed storage. And the latter is based largely on lithium.

3. The Genesis of Battery-Based Energy Storage

Lithium was first considered for batteries in German labs in the 1970s. By the 1990s, the lithium chemistry in batteries reportedly reached a tipping point in the 1990s thanks to the use of lithium-cobalt oxide chemistry in rechargeable batteries. In short, the use of these super powerful batteries in smart phones has led to their scaled up use for cars and buildings.

The Element Lithium

Now for a bit on lithium. It is the lightest metal; the lightest solid element. It holds the third position in the periodic table. It is an alkali metal, flammable, highly reactive, unstable, and never found in isolation in nature. It is found in seawater, oilfield and geothermal brines, clay, and pegmatites – with major repositories in Bolivia and Chile.

Lithium is non-toxic, unlike lead and cadmium battery materials. There are trace elements of lithium in all organisms with no apparent biological dysfunction. Lithium is still used as a mood-stabilizing drug for bipolar disorders. And presence of lithium in Cuban soils is reportedly why Cuban cigars have a mood-altering effect.

The Lithium Revolution was really kicked off with consumer electronics; lithium-ion is powering a new class of rechargeable batteries. And this battery chemistry has three major benefits: high energy density (power per unit of weight), no memory effect, and they are highly efficient. As such, they are powering up our cell phones, and now our EVs, from LEAFs to Teslas.

Note that lithium is one quarter the weight of lead acid. You can store 100 watt hours per kilogram of lithium. Thus a kilowatt of capacity weighs at least 10 kilograms, or 25 pounds.

The Fire Factor

One of the alarming issues surrounding lithium batteries is danger in the form of fire and explosion. While this may be an early hic-cup, the reality and perception of fire may have a serious effect on energy storage. Danger is an issue for the battery storage industry to grapple with. Lithium is flammable and explosive. Key to keeping lithium batteries safe is keeping them properly managed, not overcharged, and cool. Defects in cells can be deadly.

Consider this. Hoverboards are all the rage. Right up there with drones, they were the choice Christmas gift for 2015. But already hoverboards have caused fires and serious damages. We've seen alarming images on TV. While experts claim that lower-cost batteries are being used in lower-cost products, personal injury and house fires may have a deleterious effect. Better batteries are more expensive.

Then there's the Dreamliner. The entire fleet of Boeing 787 was grounded as a result of fires in its lithium battery packs. They overheated. One such incident on January 7, 2013 left an empty JAL jet smoldering on Logan Airport runway in Boston. A few days later, on January 9, UAL reported a problem on one of its six Dreamliners. On January 16, Al Nippon Airways (ANA) made an emergency landing on Shikoku Island after a computer warning of a battery malfunction. Passengers were hastily evacuated through emergency landing slides. ANA and JAL quickly suspended 787 flights, losing millions of dollars in revenues each day. By January 16, 2013, all 50 Dreamliners were grounded by the Federal Aviation Administration. The next day Boeing halted deliveries of new jets until it had a solution.

The focus of the jets' safety review was on the lithium-ion batteries, specifically those that use lithium cobalt oxide as the positive electrode. These electrodes are known for their thermal runaway hazard and provide oxygen for a fire. Now safer lithium-ion battery chemistry is available that uses LiFePo4 and LiMn2o2 (lithium manganite). On April 19, 2013, the FAA lifted its ban on the Dreamliner and cleared it for take-off. Changes were made to their battery systems to better contain battery fires. But there are simmering concerns as the root cause of the fires was not determined.

And safety issues related to lithium continue. An investigation report prepared by the FAA questioned the contents of the cargo on the missing Malaysian Airlines jet, MH370 bound for Beijing. According to its cargo manifest, on board was a 221 kilogram shipment of lithium-ion batteries from Motorola Solution Penang.

In another incident, on September 3, 2010, a United Parcel Service 747-400 crashed due to smoke and fumes in the cockpit. The flight was bound from Dubai International Airport to Cologne Bonn Airport, and was 120 nautical miles inflight when the crew reported a fire. The plane tried to return to Dubai but overshot the runway and crashed, killing both crewmen. Investigations focused on auto-ignition of the contents of a pallet in the cargo that contained significant amounts of lithium-ion batteries. The investigation led to a restriction on carrying lithium-ion batteries in bulk on passenger planes.

Naturally, the risk of fire increases in mobile applications when vibration and potential impacts are factored in. Electric cars. What if their batteries are punctured? Overcharging is common and a major concern.

There is no question that the rise of energy storage is inextricably linked to the rise of lithium-ion chemistry. As with all forms of energy, there is danger involved, and thus risk. There is a horrifying story of leading flywheel company whose "contraption" disintegrated, blowing fragments of its storied success throughout a building like shrapnel in a war.

For batteries, solutions appear on the horizon. Stationary batteries seem inherently safer, but lower-cost manufacture may threaten the safety gains made by industry majors. Without question, the safety of storage needs to be kept front and center and mitigated.

Smart Controllers for Demand Charge Reductions

The other primary element in the energy storage world, and the key to the hybrid-electric building revolution, is the element that complements the batteries: the controller. To make money through avoided demand charges and peak energy use, lithium-ion batteries are coupled with smart controllers loaded with algorithms. These controllers monitor facility loads on a second-by-second basis, responding to increased use nearly immediately. Systems can discharge in four milliseconds. Power plants take tens of minutes to get up to speed.

The controller's software is driven/informed by historical and real-time data, allowing for predictive storage charge and discharge decisions. Furthermore, their remote diagnostics learn and refine algorithms. These are the black boxes… the proprietary formulae. There are four companies leading in this programming niche. This is where money will be made and lost, where performance guarantees can lay the risk squarely on the shoulders of the providers and their software programmers.

The Fast-Pace Storage Industry

There is no question that the industry is moving very quickly. There's a California Energy Storage Alliance, the national Energy Storage Association (ESA), and recently, the North American Energy Storage Conference. Given the drive, there has been an infusion of new players and innovations. The latter are based on new technologies – better batteries and power management systems – as well as their smart controllers.

Companies are working to integrate grid power with solar and other renewables, fuel cells, microturbines, and storage. Smart software focuses on peak demand periods and peak demand charges. The integration of resources creates a loading order… a building-based dispatch that is also coordinated with utility dispatch. There are a number of market entrants in the energy storage arena. Some sell batteries, some guarantees. Some focus on one program or another to drive down overall costs.

Green Charge Networks was funded by the U.S. Department of Energy. It got a $56 million infusion of capital. Its San Francisco-based rival STEM is funded by General Electric and Iberdrola, a Spanish utility. Coda was purchased for $25 million by the

Fortress Group, a major real estate holding company. Bosch offers Bosch Energy Storage Solutions; Sharp offers "Smart Storage." We hear good things about LG Solar Battery Solutions. Panasonic has been a major battery player, as has Samsung. Familiar names riddle this new industry.

And consumers have responded to the providers' offers: Leading companies have embraced storage and the promises of lower utility bills, cutting peak demand charges. Adobe is in, as is Wells Fargo. Given island limits for power, it's not surprising that storage makes tremendous sense for Hawaii Electric. Levi Stadium in San Francisco features storage. Programs and incentives are being provided coast to coast, from Consolidated Edison in New York City to the South Coast Air Quality Management District in Los Angeles. Consumers like the Irvine Company see the benefits, they are comforted by low risks.

The Tesla Factor and Factory

Elon Musk, more than any other individual on the planet, has had a vision for storage that links mobile sources with stationary sources. He needs batteries for his Tesla cars, and batteries for his SolarCity solar projects. Combined, these two applications for batteries have justified enormous expenditures that may benefit us all and jumpstart storage like no other single move.

Musk's boldest move is building a battery "gigafactory" in the Nevada desert. By doing so, he explains, the cost of batteries for both stationary and mobile applications will be improved. Meanwhile, the gigafactory is being designed to be net zero itself.

SolarCity has announced that it will include battery banks in all of its installations in New York, Connecticut, and California. For homeowners, Tesla offers Powerwalls in designer colors. These systems will cut peak energy usage. For commercial and industrial customers, SolarCity offers larger systems with Demand-Logic contracts.

4. California's Leadership in Storage

In California, there are three primary factors that have driven the growing interest and attention to storage. First is the remarkable advance in lithium battery chemistry. We've covered that. Second is California's 1.3 GW goal by 2020 for storage. And third, are high and escalating demand charges that make offsetting these charges all the more attractive.

The California Energy Commission goal of 1.325 GW of energy storage by 2020 includes three forms: transmission grid support, distribution system support, and customer-side storage deployments. The presiding CEC Commissioner, Carla Peterson, built on the original AB 2514 goal in 2010 authored by Nancy Skinner that called for storage to provide 5% of the State's peak demand, or 2.367 GW.

So now let's be clear on storage… and how much storage we are talking. If you're on an island, you need enough storage to ride through the night, and even for days of prolonged precipitation or cloud cover. The initiatives programs presented here require four-hour and two-hour storage capacities. In other words, when called upon, the system needs to deliver its rated capacity for four. A 100 kW battery would have to be able to provide 400 kWh net of losses over a four-hour period.

In Southern California Edison's service territory, the summer peak period when demand charges are highest, is six hours long. So another option is to put storage in place for this longer period… requiring 600 kWh of storage. We have a client that is interested in six hours, but for a different reason. This school district wants to be able to operate in the event of a power failure and to be able to keep kids in their classrooms since contacting their parents for early dismissal is near impossible.

In California, vendors of energy storage systems are being propelled by quite fantastic incentives. These are provided by the California Energy Commission and by the State's investor-owned utilities. We cover two programs here and note the Preferred Resources Pilot program targeting two substation areas most impacted by the loss of the San Onofre Nuclear Generating Station ("songs"), Johanna and Santiago, in Orange County.

Self Generation Incentive Program

Currently a $77 million incentive program for a range of commercially available and emerging technologies including "advanced energy storage." It pays up to 40% of system costs through incentives. Through its administrators, the California Energy Commission currently pays $1.31/watt of storage capacity, plus a 10% bonus for California suppliers. Tied to this incentive is a requirement that the batteries can coast through two hours of discharge. In other words, a 10 kW battery bank must have at least 20 kWh of storage. In New York State, a similar program has a six-hour discharge requirement. These incentives and their requirements shape vendor offerings. For SGIP, California suppliers get an additional 20% incentive. It's first-come, first-serve and very competitive.

<u>Demand Charge Reduction Services</u>: Attractive incentives spur businesses. In terms of storage, there's a new business on the rise, and it's about strategically offsetting demand charges and "future proofing" tariff changes. The business is hot where the incentives are hottest. For providers, the trick is to find attractive load profiles, and then to use the least amount of battery to deliver the greatest economic savings by offsetting demand charges. Like solar installations aimed at maximizing rate offsets, there are "sweet spots" in sizing storage systems, naturally linked to today's market prices of lithium-ion batteries.

Demand charges are based on the capacity of a host site, and constitute about half of a typical commercial bill. A business's demand charge for the month is based on the highest 15-minute interval of use for the entire month. If a storage provider can find that moment, or those moments when the peak is set, the provider can deliver savings in the form of a reduced power bill.

The systems make sense because of high and escalating demand charges. While consumers can take control and hedge against future utilities prices by investments in efficiency and renewables (that cut kWh costs), heretofore they have not been able to control demand charges (kW). In California, the demand charge portion of the bill has been increasing steadily for at least a decade… utilities have loaded their capital costs on the demand side of the bill. Now with batteries, these charges too can be controlled and mitigated.

As such, companies such as Green Charge Networks, STEM, and Coda are promoting storage systems to users. Some are fully financed. Others have performance guarantees that assure a host site of saving a set number of dollars each month through demand charge reductions. Shared savings have hit batteries.

Here's the CODA offer for its storage systems: There's no upfront cost for client. There are no payments required at all in first year as the first year determines baseline savings. Thereafter, savings are split 50:50 for life of product. The systems have a ten-year warrantee and are manufactured "locally" in Monrovia, California.

Another innovation is Power Efficiency Agreements (PEAs). They are offered by Green Charge Networks and are comparable to PPAs for solar and other renewables, where a consumer pays for green electrons. A PEA enables a consumer to get batteries on site with no money down. Then there is a share of the demand-charge savings. SolarCity offers a similar storage option when it sells a client solar, called Demand Logic. In addition to a PPA with SolarCity, a host site signs a contract for demand charge reduction and a share of the resultant savings.

Local Capacity Requirements

On November 5, 2014, Southern California Edison announced the winning bidders in its Local Capacity Requirements (LCR) program. The solicitation was for 2,200 MW of capacity, generally to offset the loss of the San Onofre Nuclear Generating Station (SONGS). The LCR's target area stretches from North San Diego County to Ventura County and East LA and was open to gas-fired generation, combined heat and power, demand response, energy efficiency, energy storage, renewables, resource adequacy, and distributed generation.

Per CPUC rules, the open solicitation required that Edison procure a minimum of 50 MW of energy storage. (The Commission also required 150 MW of preferred resources – efficiency, renewables, and DR). At the end of the day, over 250 MW of storage was procured, provided by STEM (85 MW), AES (100 MW), ICE Energy (26.5 MW), NRG (0.5 MW), and AMS (50 MW). Proposals included in-front-of-the-meter and behind-the-meter solutions.

While the overwhelming majority of resources procured by Edison were conventional, this was a first time that energy storage competed head-to-head with conventional resources. Of the 2,200 MW solicited, AES won the right to build and operate a 1,284 MW combined-cycle gas fired turbine; NRG got the nod for a 316 MW gas-fired, peaking plant. But storage purveyors were also pleased, valued as a robust utility resource.

5. Stacking Storage Programs for Maximum Benefit

Fascinating is the storage path. Beam us up. This is about microgrids heightened interconnectivity. It's an industry just breaking its britches! For many of us, it's like drinking out of a fire hose, a favorite Dave Bill quote on a common mentor, Amory Lovins. The equipment is shiny and costly.

We've been digging it, batteries and their power electronics and hot-shot algorithms. We know of ISO and RTO clauses in contracts, but what's happening here? Mixing and matching customer services with utility services in battery configurations? Is that possible? Are there also ISO programs that might be tapped? Could the same batteries be serving one, two, three, or more purposes?

A study by Rocky Mountain Institute catches our attention: "The Economics of Battery Energy Storage." I'm impressed that the report is downloadable for free. It's great research that even makes me a bit proud as the first Energy Program Director at RMI.

The report spells out thirteen services that can be derived from battery-based storage systems. It also makes clear the value of a third dimension of benefits: All behind the meter, adding to consumer benefits and utility benefits are grid benefits. This is critical because batteries are expensive, really expensive.

Thirteen Storage Services

Let's back up a bit and span thirteen storage services that batteries can provide. RMI presents them as Customer, Utility, and ISO/RTO services.

Customer Services

- Time of Use Bill Management
- Increased PV Self Consumption
- Demand Charge Reduction
- Back-up Power

A few words on each: Time of use bill management is about household or building level energy arbitrage, buying cheap power at night, storing it, and then using it during the day and at peak periods... avoiding high cost power. This can also be done with solar power, especially in the absence of net energy metering. An even more lucrative option has been demand charge reduction, “picking off” peaks in the load profile. In each case it’s about shifting off the peak to avoid expensive peak capacity and power. And then there’s emergency back-up. While critical, batteries may be a very expensive way of achieving this goal.

Utility Services

- Resource Adequacy
- Distribution Deferral
- Transmission and Congestion Relief
- Transmission Deferral

Utilities across the nation deserve great praise for embracing the energy storage revolution as firmly as anyone else. Storage is a critical element in their successful operations. And much of the utility action is at the utility scale… providing voltage support and other ancillary services, dispatchable capacity at its finest.

The Duck Curve and Batteries

And then there are power system dynamics: Presently many utilities are facing issues surrounding too much renewable power. In many instances, while beneficial overall, it’s coming on the grid at the wrong times. And when it drops off – say when the sun sets – there is an issue with quickly ramping up more conventional sources. While years ago utilities grappled with mountainous load profiles, today they are grappling with the “duck curve,” a load profile shaped by renewables on the system. Battery-based energy storage can help.

When it comes to the customer’s side of the meter (what is oft called “behind the meter”), utilities have another opportunity. There is a megatrend towards DG (“distributed generation”) and now DS (“distributed storage”). Their combination is what some call “distributed energy resources” or DES. Proactive utilities are embracing DES, providing for its effective integration and taking fair share of its profits. For decades, utilities have owned the means of production at a centralized scale. Now with advances of lithium-ion batteries in particular, utilities can find common value in energy storage. RMI documents four utility services:

Resource Adequacy is all about having adequate resources to keep the lights on! And it gets down to a circuit and substation level. Southern California Edison's LCR program requires participants to be able to deliver power upon demand for four-hour periods.

Then there's Distribution Deferral. In a Consolidated Edison program, the batteries are committed to be available specifically for distribution system upgrade deferral for 120 hours each year during summer substation peak events. This leaves the batteries available to provide other services for the remainder of the year.

The Brooklyn-Queens Demand Management Program (BQDM) program has built an aggregated fleet of 4,000 residential systems (5 kW/10 kWh) and 1,500 commercial systems (30 kW/90 kWh), providing an aggregate capacity of 65 MW/175 MWh.

Third and fourth relate to the transmission. Transmission and Congestion Relief is third and sounds like its time for Tylenol PM. Transmission Deferral is fourth and less likely to be employed by system planners.

ISO/RTO Services

- Energy arbitrage
- Frequency Regulation
- Spin/Non-Spin Reserves
- Voltage Support
- Black Start

The third form of services are ISO / RTO Services, what are commonly called "ancillary services" in the industry. ISO stands for Independent Grid Operator. In California, we have "CAISO." In other areas there are Regional Transmissions Organizations that manage the grid. Grid benefits provided by batteries are mostly hidden, but are critical and valuable. Consider frequency regulation:

Frequency Regulation: For the history of grids, operators have had to balance consumer demand with power plant production. The balance must be maintained every second, and the balance is routinely upset by changes, plant outages, as well as consumer demand. Imagine Dodger Stadium's lights powering on all at once! A utility has to balance the frequency of the power it delivers, as well as the power factor of the power it delivers. Utilities have been required to maintain spinning reserves, generators that can ramp up or that spin idly for on demand delivery for balancing purposes. Now these functions can be provided by batteries, in literally split-second time.

Energy Arbitrage suggests buying power on the cheap, storing it, and selling it high. I remember being at LADWP in 1998 when the CAISO used our storage, paying us to take excess power off the grid. LADWP then turned around and sold the power during peak periods. Voltage Support, maintaining a neutral power factor, is critical too. Black Start refers to powering up the grid after a major outage and being able to use stored power to fire up conventional power plants much like a car battery.

Ancillary Services

The more batteries that are employed in the fingers of the distribution networks, the more ancillary services like frequency regulation and power factor correction they can provide. In restructured power markets – like California and New York – these services are bought and sold, traded in an open market. In fact, FERC Order 755 mandated utilities to purchase these services from eligible providers in their service territories at fair market values.

And the picture is even brighter. Batteries can be deployed in milliseconds… far faster than any other form of spinning reserve. Power plants can take hours to power up; actual spinning reserve is wasteful mechanical energy. As such, battery-based energy storage is a more valuable balancing asset than traditional sources. In some cases, balancing can be worth as much as $200/MWh, far more than the more typical balancing prices in the $10 – 50/MWh range. Note also that ancillary services can be provided and monetized at time scales well below an hour.

Stacking Services

The industry lingo is vibrant, there's talk of "stacking" and "mileage." "Stacking" or combining services makes sense since batteries are expensive. In some applications – like emergency back-up power – batteries may be used 1-2% of the time. The rest of the time the asset sits idle and unproductive. Expensive assets need to be fully utilized to warrant their investments. Stacking allows for this. Mileage is the amount of run time and storage capacity of the batteries used in discharge and charging periods.

In some cases, like ISO balancing, a battery storage system can be simultaneously providing an ISO service while serving another function, be it customer load leveling or utility resource adequacy. Just as power plants are dispatched, storage systems can be dispatched to different programs, prioritized by incentives and penalties.

Some contracts allow for multiple users of batteries, with a utility "referee" to determine who gets the stored energy. There's a pecking order. In some cases, battery providers may have calculated that it is better to pay periodic penalties for not being able to deliver… and to stack programs for net benefit. The rules for use of storage – and stacking systems – are being developed. There is considerable uncertainty about contracts and pricing. In many states, current regulations on dual participation use cases are unclear. Some utility territories have allowed only one program per meter at any given time.

The RMI report clarifies the opportunity, and the reality of storage today: " Most systems to date are comprised of single-use, underutilized batteries. These batteries may sit un-used for anywhere between 50 – 95% of their useful life when dispatched to only one primary service. This is a waste of a useful asset, and increasing the utilization factor of batteries by re-dispatching them for an additional stack of services once their have performed their primary intended use (for instance demand charge reduction) can create additional value for all electricity system stakeholders."

So how much stacking is going on? And is it possible? Conceptually yes, and there are a handful of innovative companies crossing the lines and tapping the multi-revenue, battery-based storage model. But while intriguing, we're very early in the game. To date "a stacked business case is not being deployed today except in a handful of special projects."

Being in the battery-based storage business must be exhilarating and daunting. It's the Wild West, complete with market and regulatory variables, technical variables, and primary dispatch constraints. As such, a new class of dispatch models have been developed to optimize on the use of expensive batteries. Instead of single use, smart providers are looking about how to provide secondary services based on the relative value of the service, battery availability and state of charge, and other user-defined inputs.

6. Conclusion

Energy storage is an exciting field. It's full of new goals, players, initiatives, and innovations. It's about technology and smart controls that can predict peaks and thus stem costs.

Right now, several deals are indeed penciling. Demand charges and incentives are great enough to warrant installations of fully financed systems. Hopefully as incentives follow a degressive schedule, the costs of storage systems will commensurately fall.

Reducing Risk: EcoMotion cautions its clients to reduce risk. This is a new technology. We like third-party financing and performance guarantees, especially ones based on dollars. Mike Peevey, former CPUC president, commented to me recently that what people don't realize is that rates can change. Generally, storage works in areas that have high demand charges. Rate changes – particularly those that cut demand charges (done by correspondingly increasing energy charges) -- could dramatically upset the benefits projected by purveyors of these systems. Many rate changes are done by utilities incrementally and with advice filings. As rates change, the economics of storage systems do too. This, of course, is true of efficiency and renewable investments as well. So beware.

The Next Generation: The future of storage will invariably be different than what we see today. While lithium-ion battery chemistry is exciting in its current state of development, allowing for its widespread use and profit today, perhaps it is paving the way to our future.

There will invariably be far more effective storage solutions. The next generation will no doubt advance battery chemistry and storage systems “smart” controls. Already experts are bubbling about the great efficiencies in flow batteries, vanadium redox. Then there’s the promise of a whole new class of plastic batteries known as super caps and ultra caps.

Hydrogen: Some years ago, it certainly appeared that the best solution for electricity storage would be hydrogen. Renewables would first be used to generate electricity directly, with surplus renewables used to electrolyze water to form hydrogen. This fuel can be stored and later burned or run through highly efficiency fuel cells. Hydrogen – in gaseous and solid crystalline form – may still be an important storage medium, far lighter than the best of lithium-ion batteries.

Ride the Wave: But I am reminded of Evan Mills and what he loved to say, and may still say: “Ride the wave!” Advanced energy storage represents a major swell of activity. There are major benefits to consumers and society alike in storage. The incentives are strong in many parts of the country. Be a part of this… and ride the wave!

EcoMotion ‘s mission is the cost-effective greening of cities, corporations, and campuses. We’re an owner’s rep… helping to find beneficial arrangements for our clients. Our storage team includes Ted Flanigan, Michael Ware, Troy Strand, Drew Lowell-Britt, and Thelma Rodriguez-Winter. Currently we are working with the Irvine Ranch Water District, Garden Grove Unified School District, Poway Unified School District, and Santa Rita Union School District on battery-based storage solutions. This White Paper presents EcoMotion’s perspectives, shaped by many, notably Troy Strand, Frank Tom, Greg Weyl, Chris Baker, Susan Kennedy, and Patrick Sheilds.

Appendix: Storage Opportunities for You

This section is primarily written for power users like you. EcoMotion is focused on "behind the meter" storage, located on host sites. And the benefits can be win-win-win between customer, provider, and utility.

EcoMotion begins with six fundamental screening questions:

1. How big is your load?
2. How "peaky" is your load profile?
3. How much do you pay for power?
4. What electricity rate are you on?
5. Do you already have solar?
6. How important is emergency power to you?

How big is your load?

First off, how big is your load? What's your average load? Your peak? Is this going to be worthwhile? Tesla's new residential PowerWall stores as little as 7 kWh. Right now, aggregators like STEM and AMS are looking for large consumers, typically buildings or facilities with power use in the 200 – 500 kW range. (Yes, there is movement on the residential scale, see SolarCity/Tesla and Sunverge Integrated Solutions.)

How flat is your profile?

Next, flat load profiles may and may not work well for storage solutions. Depends on how much storage you can afford and how deep you want to cut your demand charges. For short-duration batteries, peaky load profiles are perfect. For the smallest storage solutions, one needs not only mountainous load profiles, but those with tiny spikes in peak demand that can be flattened.

How much do you pay for power?

Electricity rates often dictate the efficacy of storage systems. It's important to review both demand charges in different seasons and time periods, and to assess the value of avoided peak energy charges. Similarly, demand charges will drive demand charge savings. We learn a new distinction, that storage systems are both "demand responsive" and "price responsive."

What rate are you on?

Note that the presence of solar, and notably the Option R in SCE/DG-R in SDG&E rates, can diminish the value of storage. These rates reward customers for going renewable and reduce summer peak and mid peak demand charges, but thereby reduce the value of storage solutions specifically intended to cut demand charges.

In some cases examined by EcoMotion, the value of solar completely offsets all energy and demand charges, making the incremental cost of storage unnecessary to spend as its benefit would be zero. In other cases, storage "plays well with solar," as a site's peaks are often not covered by solar.

Then there are demand charge periods that vary: SDG&E not only has the highest demand charges in California, but it also has the longest summer peak period. Summer in San Diego is a full 6 months, May – September! This is good for storage!

Another nuance of importance at scale, is how peak demand is calculated. For instance, PG&E determines the maximum peak in each 15-minute interval by calculating the average of the three peaks every five minutes. Other demand charges are calculated differently.

Is emergency power important to you?

While more expensive, storage can be used in place of conventional emergency back-up systems. This is more of a UPS function, and may be useful where noise and placement of batteries is unacceptable. Naturally, the more critical emergency power is to you, the more you will be willing to spend on it. For a client, we're evaluating critical loads and shut-down protocols for all other uses in emergencies.

Consumer Opportunities

Provided that a site makes sense for storage, there are a number of consumer options:

The Purchase Option

The first option for consumers is to buy battery systems. They cost about $10 per watt for residential applications, and on the order of $3 a watt ($3,000/kW) for commercial systems. This capacity cost is quite similar to solar. As is the case with solar, residential storage systems are more expensive, priced in the $5-7/watt range. Do note that batteries also are priced in terms of energy stored, thus dual pricing for capacity (kW) and energy (price per kWh).

STEM offers a 18 kW/60 kWh tower, about the size of a gym locker, for about $47,000 after incentives. It claims a 2.5-year payback on a typical, viable installation. These systems will be priced monthly too, at a charge of $280 – 300 per tower per month, or $3,600 a year. STEM's new product is a 100 kW/200 kWh, calculated to have a typical 4-5 year payback.

Buying systems allows an owner to reap the full benefit of current incentives, potentially tax credits, and the full benefit of the demand charge reductions realized. Combined solar and storage systems built and interconnected may be able to potentially monetize the 30% Investment Tax Credit for the combined system. This must be done with care: For storage systems to be eligible for the tax credit, the batteries must be powered with solar at least 75% of the time. The flip side of ownership is risk: these are new technologies with relatively unproven performance records. In addition, utility rates can change, potentially stripping away demand savings.

Third Party Arrangements

The second option is to engage in third party financing. Much like the solar PPA, several battery companies will finance systems and then share savings. This eliminates much risk, but also takes away about half of the savings.

Tesla was the first battery provider to offer residential systems. Partnering with Green Mountain Power (GMP), a partnership was announced in December of 2015 that allows customers to buy or lease Powerwall systems for their homes. Powerwalls can either be paired with residential solar or as standalone battery to store power from the grid. They can either be exclusively for household use, or they can be "shared" and integral to the power grid, called upon for voltage support and other ancillary services.

GMP offers three options for consumers, with varying degrees of shared access… in other words utility access. Leased systems with complete shared access cost $37.50 a month. Another option is to purchase the Powerwall for $6,500 and share its access and get a bill credit of $31.75 a month. Third, buy it outright with no shared access for $6,500.