Batteries Included

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OVERVIEW

California's recent passage of the world's first energy storage mandate could be the tipping point for this versatile smart grid tool. Expanding storage will also help grow the percentage of energy we get from wind and solar energy. Entrepreneurs and governments are teaming up to conduct field tests, bring down costs, improve efficiency, ensure safety, and facilitate access to the grid and market.

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BY ERICA GIES

Last month, a Central Valley almond orchard played host to a meaningful step in our journey to cleaner energy. Employees of tech startup EnerVault gathered around their creation: rectangular metal boxes, sort of like shipping containers with doors, backed by four tall, cylindrical tanks. In the presence of federal, state, and electric grid officials, they flipped the switch, and this new type of battery for grid energy storage powered up.

The event was a snapshot of California's rapid, recent emergence as a hotbed of innovation in one of the wonkiest sectors of the already wonky smart grid. The energy storage market here has been supercharged by the California's world-leading policy to mandate energy storage and by investment from the U.S. Department of Energy (DOE), federal policy, and private capital.

Redox flow batteries hold electric charge in tanks of electrolyte. EnerVault's innovation was using iron-chromium chemistry, which is less expensive than other types of redox flow batteries, and making it more efficient than earlier iterations. The project was funded by $4.7 million in DOE money through 2009's American Recovery and Reinvestment Act, $476,000 from the California Energy Commission, and $30 million in venture capital.

Copyright: EnerVault. The Turlock project.

Suddenly, after years in the wilderness, storage is arriving in its Canaan. For years, “energy storage conferences were basically support groups for guys who had passion and belief but couldn’t find a market or customers,” said EnerVault CEO Jim Pape. For that reason, the battery’s dedication in Turlock, Calif., “was the most cathartic event,” he said. “We see the end of the tunnel now, and that’s an exciting thing for a startup that’s been talking to people who were just oh so skeptical.”

In case you haven’t spent the past 10 years researching and writing about the electricity grid (ahem), here’s a primer: To keep power flowing reliably, grid operators must smooth out supply and demand second-to-second (called frequency regulation), hourly (to address intermittency), and on a daily, weekly, and annual basis (to meet peak demand).

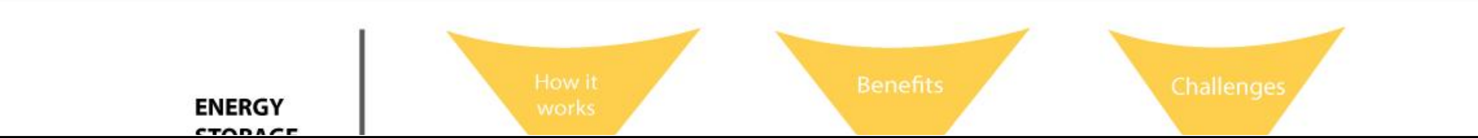
Historically, most grids haven’t stored much energy because it’s been expensive. Instead grid managers relied on extra fossil fuel plants to ramp up and down as necessary to provide these services. But fossil fuel plants run most efficiently at full power, so using these extra "peaker plants" to smooth the flow is even more polluting than burning fossil fuels for baseload power.

Over the last decade, pressure has mounted to shift our energy consumption to less polluting forms. Carbon capture and storage, nuclear, and natural gas have all had – and lost – their moments in the sun as popular solutions to reducing greenhouse gas emissions. Meanwhile, wind and solar have been steadily increasing market share and becoming cost competitive in many areas. Their portion of the electricity mix has been steadily ramping up in various places around the world, including Germany and California.

But wind and solar are intermittent energy sources: the sun doesn't shine at night, and in many places, wind slows during the day. They also add to the grid's need for frequency regulation when a cloud passes across the sun or the wind drops off suddenly. So as their percentage in our energy mix increases, and as we ask the smart grid to do more things, the entire system needs added flexibility. That can be addressed via demand response (a capability often built into appliances to balance supply and demand by turning power off and on in tiny bursts); new operating procedures, business models, and market rules – and storage.

California is on the leading edge of this new market thanks in part to its target of 33 percent renewable energy by 2020. Several years ago, learning a lesson from Germany's grid limitations as it expanded its share of renewables – and perhaps because the large amount of solar California already had installed was beginning to affect voltage – the state's industrial and political leaders honed in on storage as a key component of the smart grid.

Momentum began to shift in a big way last October, when the California Public Utilities Commission (CPUC) passed the nation's first energy storage mandate, requiring the state's three largest utilities to use 1,325 megawatts of energy storage by 2020. The move put into action a 2010 law passed by the California legislature, AB 2514, that required the PUC to set storage targets.



STORAGE TECHNOLOGY			
Lead-acid batteries	The oldest type of rechargeable battery, lead acid batteries store energy via lead electrodes with dilute sulphuric acid as the electrolyte.	Little to no geographic constraint; can be deployed for bulk services, frequency regulation, transmission and distribution applications, distributed storage, commercial and industrial applications	Fire hazard; end-of-life disposal
Lithium-ion batteries	Rechargeable battery in which lithium ions move from the negative electrode to the positive electrode during discharge and back when charging.	No geographic constraints; can be deployed for frequency regulation, wind integration, transmission and distribution, distributed energy storage, commercial and industrial applications	Fire hazard; cost
Iron-chromium batteries	Energy is stored via transfer between iron and chromium molecules, dissolved in liquid electrolyte.	No geographic constraints; can be deployed for bulk storage, PV integration, wind integration, utility transmission and distribution, commercial and industrial	Potential for unwanted side reactions
Pumped hydro	Uses electricity to pump water up to higher elevation reservoirs at night, then release it during the day to meet peak demand.	Use of nighttime energy, lower emissions than conventional power sources, better management of peak demand	Environmental concerns similar to those associated with dams, extensive permitting procedures, require sites with specific topologic and geologic characteristics.
Compressed air energy storage (CAES	Uses electricity to force air into a cavern. To extract it, operators heat the compressed air, often using natural gas, then push it through turbines to generate electricity	Can make use of nighttime wind energy, lower emissions than natural gas, similar to pumped hydro without the environmental impact issues.	Geographically dependent on areas with appropriate caverns; systems that use natural gas, rather than capturing and re-using waste heat, are inefficient.
Flywheel	Uses electricity to drive a motor, which accelerates a massive disc, storing electricity in the increased momentum. It is released when the flywheel drives the motor in reverse.	No geographic constraints; small footprint; low maintenance costs; long life; can cycle quickly from charge to discharge	Noise pollution; potential safety concerns; best used for high-power, low-energy applications that require many cycles; utility-scale would require the buildout of "flywheel farms"
Thermal energy storage	In the hot version, the storage medium, such as salt, stores daytime heat, using it to produce electricity after the sun goes down or during cloud passage. In the cold version,electricity is used to freeze a block of ice at night when the air is cool and juice is cheap, then dispatched during the heat of the day to reduce peak AC load in the summer.	Few geographic constraints; can be deployed directly to the grid or used at power-generation sites	Costs and efficiency vary wildly depending on specific technology used; stability can be an issue depending on the storage medium.

Services Rendered

While energy storage can provide frequency regulation on the grid and help stabilize the flow of intermittent wind and solar, it can also perform many other new tasks that are required as we move to a smarter grid.

Our electricity system is hugely inefficient, overbuilt to serve that one afternoon in August when it's 95 degrees and everyone is cranking their AC for dear life.

"California has an average load factor of 55 percent," said Janice Lin, co-founder and director of California Energy Storage Alliance (CESA), a coalition working to expand energy storage and renewable energy. "We only use our electric power system about half the time. If we can use that existing infrastructure more efficiently, using energy storage to deal with spiky demand, we'll see big-time savings for rate payers."

For example, storage can also delay the need for expensive new transmission lines, saving utilities and customers money. By charging storage devices at night and discharging them during the day to flatten demand, "the pipe doesn't need to be as fat," Lin said.

Of course, storage can provide backup power in an emergency, a service that appeals to business, industry, and residential customers as well as grid managers.

Storage can also help utilities get the best price for the energy they generate via a strategy called time shifting. Energy managers can store lower-cost energy produced at night, then release it to the grid during peak demand when it is more valuable. Both traditional power plants and wind farms often produce much more energy at night than can be used.

Copyright: U.S. Army Corps of Engineers. The Seneca Pumped Storage Generating Station in Pennsylvania. Managers use electricity to pump water up to the higher elevation reservoir, then release it later, as needed. Many of the 40 pumped hydro facilities in the United States were built in the 1960s and '70s to store nuclear energy generated at night, when demand was low.

Time shifting promises to be a particular boon to commercial and industrial customers, especially in California, where peak tariffs can account for as much as 40 percent of their total electricity bill. "You pay for the highest demand in power in any one 15-minute interval," said Lin. "One surge, and you pay for that peak all month. The value of clipping that peak is driving consumer interest in storage, said Lin.

Thermal storage is a useful tool for this purpose, said Greg Miller. He's the executive vice president of market development for Ice Energy, based in Glendale, Calif. The company's Ice Bear thermal energy storage system uses electricity to freeze a block of ice at night when the air is cool and juice is cheap.

It is integrated with air conditioning units and dispatched during the heat of the day to reduce peak AC load in the summer.

Although all of its projects are funded by utilities directly or via rebate programs, Ice Bear systems sits on commercial buildings – and soon homes as well. In some cases, Ice Energy has negotiated power purchase agreements with clients, which is sort of like a car lease – if it extended for 20 years.

Business is booming, said Miller. “We’ve doubled our revenue from last year to this year. And we’re anticipating triple growth this year.” That’s even before the state mandate-driven projects kick in, he said.

Bleeding Edge

Still, “it’s hard to underestimate the importance of forward-thinking policy and regulations that create market signals that don’t mandate specific technology outcomes,” said Jeff Anderson, executive director of CalCharge, a battery energy storage consortium. “The amount of venture capital and finance flowing into this space has hockey-sticked."

Germany has a well-deserved reputation in renewable energy leadership thanks to its targeted *energiewende* (energy transition) policies. But at a global energy storage conference in Dusseldorf in March, it was clear that California is dominating in storage. Due to tremendous over-generation of renewable energy, Germany is having to sell excess power at a negative price into neighboring countries, said EnerVault's Pape, who attended the conference.

Anderson was at the conference too. "Every single person from California who attended said they couldn't walk more than 10 feet without someone asking them about how they tapped into opportunities in the California market," he said. "It's dramatic and shocking the impact it's had, and the rest of the country and world are trying to catch up."

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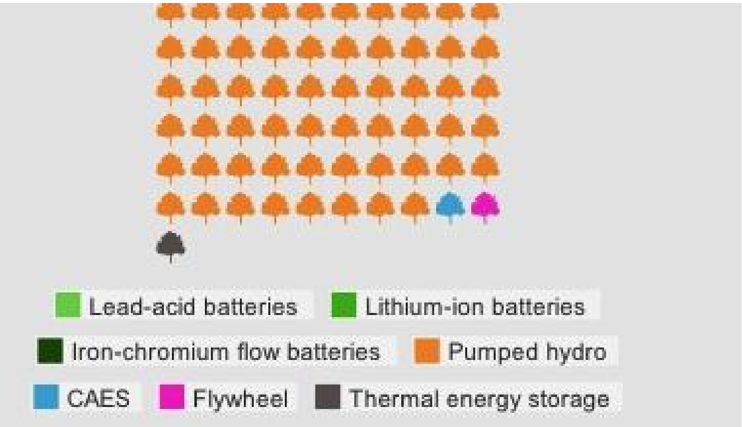
Working to retain this edge is CalCharge, which brings together companies, academic and research institutions, government bodies, and financing sources to jump-start energy storage technologies. It has identified almost 130 companies in California working in electrochemical storage, a figure that includes electric vehicles and personal electronics.

CalCharge launched in April to fill key gaps in what was otherwise a rich development ecosystem, including world class national laboratories and research universities, investment capital, IT companies, and a regulatory environment conducive to creating market signals to drive demand, said Anderson.



For example, it was difficult for companies to access university and lab expertise at the speed of business. It could take months to a year for a company to negotiate a single cooperative research agreement with Lawrence Berkeley National Laboratory. “Anything written by two acts of congress is, by design, not user friendly,” said Anderson. So CalCharge negotiated a master of services agreement with the lab, and now any company that joins Cal Charge can start that relationship within 10 weeks, he said.

The need to hire good people, fast, is another common challenge for CalCharge members. In response, the consortium worked with San Jose State University to create the first masters in engineering with a focus in batteries, Anderson said. “Those programs will launch this fall. We have critical mass for enrollment already," he said.

Federal Policies

Storage has also become more viable in the last few years thanks to the Federal Energy Regulatory Commission (FERC), especially under the leadership of former Chairman Jon Wellinghoff, who stepped down in November last year. Long-standing market rules revolved around centralized, fossil fuel generation, discriminating against innovations like demand response, distributed generation, wind and solar, and even energy efficiency.

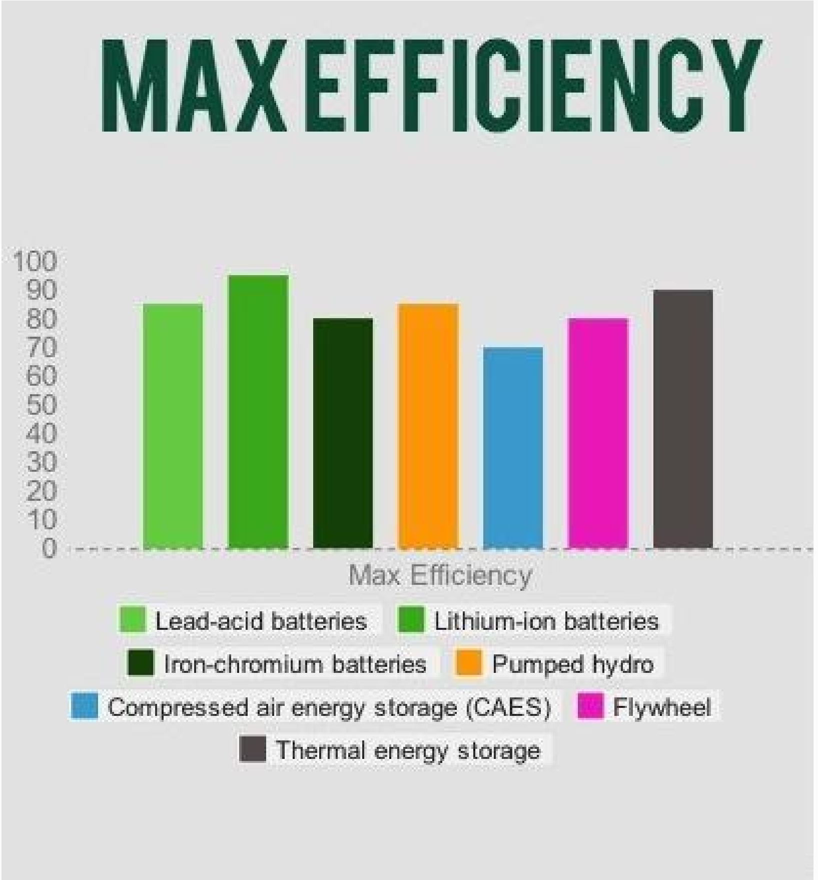
For example, storage was not a recognized asset – only generation, transmission, distribution, and load facilities were. So it was impossible for storage developers in most markets to get paid for the grid services they could provide. Several FERC orders between 2011 and 2013 – 719, 745, 755, and 784 – focused on revising market policies to allow electricity storage providers to compete in the market.

These rules also introduced the idea that better service should be better compensated. For example, storage can provide frequency regulation nearly instantaneously, whereas a gas plant takes five minutes to ramp up or down. So if storage provides a more valuable service, it should earn more, said Wellinghoff.

The Almighty Algorithm

And that's really the crux of the storage story: What can it do for the grid? And how can it best do that? It's not just about building a better battery. It's also about when to charge it and when to discharge it, like Kenny Roger's gambler: you've gotta know when to hold 'em, know when to fold 'em.

Intelligent software is key to figuring that out, said John Jung, CEO of Greensmith Energy Management Systems, a Rockville, Md.-based dispatch software company. Greensmith delivers turnkey systems by purchasing batteries on behalf of utilities and independent power producers and also sells its software a la carte for use with utility-chosen batteries. Its software offers superior data analytics and programming capability, said Jung.



A single storage device can solve myriad grid problems – if it's programmed to do so. "We believe that return on investment of energy storage systems is not just a function of cost but of how many value streams you can capture," said Jung, who lives in the San Francisco Bay Area, where the company has an office. While all storage systems use programmable software, "a lot don't benefit from any meaningful level of intelligence or algorithms," Jung said.

"There's a view that storage is basically a plug-and-play exercise. That could not be further from the truth," he said. It's a system of systems; it's complex." Rather than thinking of it as batteries in a box, "it's much more useful to think of storage as a distributed computer that can be networked, moved around, optimized," Jung said.

Greensmith's revenues are forecast to increase by a factor of four this year, said Jung. It's an exciting time – but still early. "There have been some notable fires and other incidences out there in storage world which have to be avoided," he said. "I don't want such exuberance that people deliver mediocre systems that don't perform – or worse. Otherwise the industry will set a bad impression out of the gate."

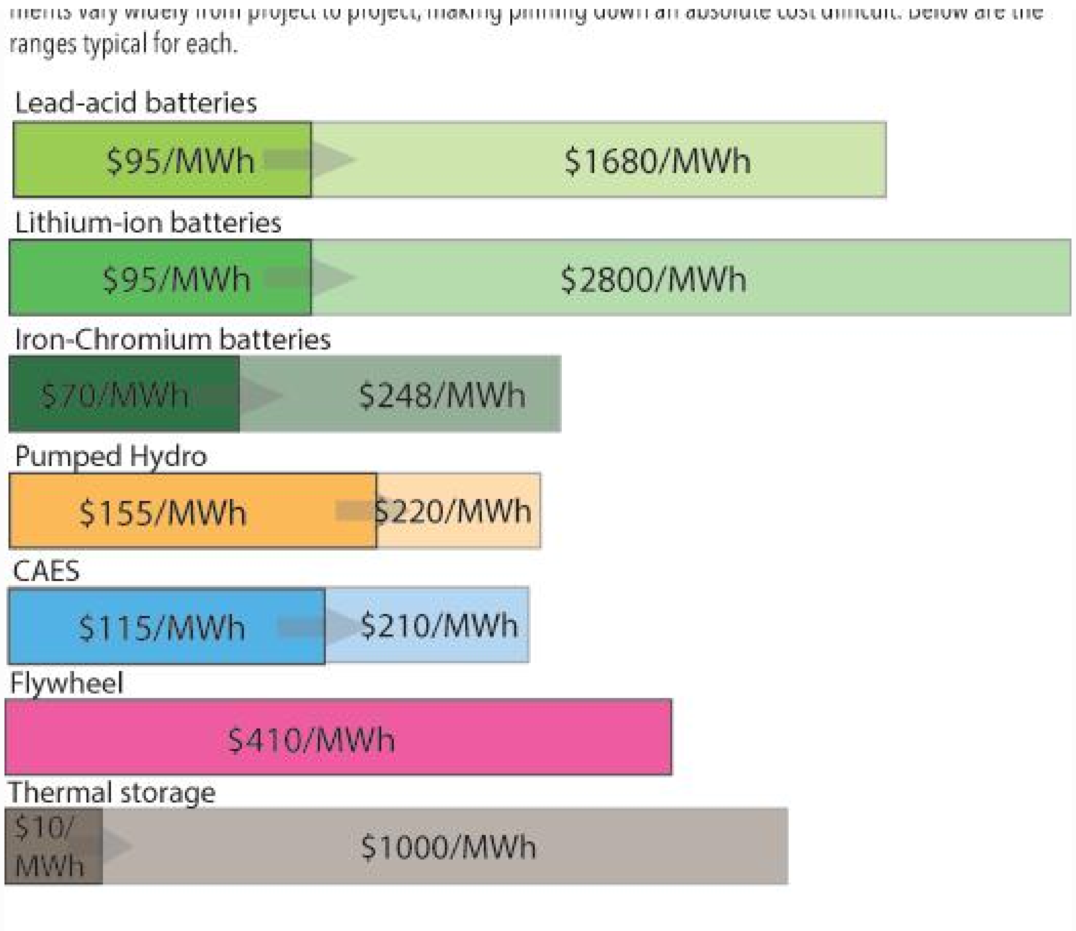
Other Pieces of the Future

Grid-scale storage likely won't be the only solution to some critical grid tasks.

For example, utilities and customers can shave peak demand with energy efficiency incentives or appliances that offer demand response. Businesses and homeowners with rooftop solar systems may install their own behind-the-meter storage devices to help them be more self-sufficient in an emergency.

Electric vehicles, if they ever become popular, could also impact the grid in a big way with their heavy charging requirements. But they could also serve as a fleet of storage devices via a concept called vehicle to grid. Also, EV charging podiums can be configured as small storage devices that sip energy slowly to avoid large demand spikes when vehicles plug in.

Grid-scale storage is still grappling with safety concerns, efficiency rates – that is, how much electricity is lost in the process of storing and releasing it – and bringing down costs. Nevertheless, after years of incremental technological and regulatory progress, the energy storage industry seems to be tipping into relevance.



Expanding Impact

California’s policy leadership has prompted other regions to enact or consider storage policies, including Hawaii, New York, Puerto Rico, U.S. Virgin Islands, and Ontario, Canada. The New York regulations “would not be happening without California’s leadership,” said Anderson.

In addition to state policies in New York, the Long Island Power Authority (LIPA) recently put out a request for proposals (RFP) requiring a 12-hour storage capacity, longer than many storage technologies are designed to provide. However, redox flow batteries can be scaled up to the task, and EnerVault has put in a bid.

Pape, EnerVault's CEO, said he thinks that Superstorm Sandy convinced LIPA of the importance of utility-scale backup power in the event of an emergency. "During the storm, they couldn't pump gas for ambulances," he said, adding that the Long Island RFP is a sign of things to come. For example, San Francisco could use similar backup for earthquake risk, he pointed out.

Validation also comes from the old guard's interest: French oil and gas company Total is now an investor in EnerVault as well as other solar and storage companies. Further affirmation lies in the growing number of storage projects around the world, tracked by a user-friendly Department of Energy database.

"The world has changed so substantially for the life and times of those of us chasing long-term storage," Pape said.

Copyright for header photo: Ucilia Wang. The lithium-ion battery system is part of a smart grid installation at the Santa Rita Jail in Dublin, Calif.

Infographics by Amy Westervelt.

Sources for infographics: Sandia National Laboratories (with the Electric Power Research Institute); National Renewable Energy Lab; International Renewable Energy Agency (IRENA); U.S. Department of Energy (plus DOE energy storage database); Purdue University; Energy Information Administration; and International Energy Agency.

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Otmar • June 11 at 12:55 am

Thank you for the comprehensive article.

I'm happy to see coverage of this vital element needed to enable large scale implementation of sustainable energy. To quote Tesla CTO JB Straubel from his keynote address at the Annual Energy Storage Symposium: "We Should All Be Thinking Bigger".

In regards to educating the public, I like to keep a basis of numbers and physics that we can follow. To that end I find it confusing that the California mandate requires "1,325 megawatts of energy storage". Are they only specifying peak power capability with no concern for energy capacity? I would expect to see a requirement for both peak power in megawatts as well as storage energy in megawatt-hours. It seems people are still expressing units in the old school way that applied to power plants capable of supplying full power anytime fuel is supplied. LIPA is listed as requiring a 12 hour storage capacity, but at what average and peak power levels? It seems the utilities and their news releases have not yet grown accustomed to specifying power together with energy. Maybe they could drive an EV for a while to get used to the new concepts around energy storage. :-)

Considering the relative high cost of stored energy, I found it interesting to use the top of my screen and scrolling to simulate horizontal lines on the "Max Efficiency" graphic. The spread between competing technologies is quite significant.

For backup power I use switches and cables to connect an antique GE electric tractor to my solar array when the grid fails. I'm looking forward to the day when localized grid storage units make that process automatic and robust!

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