The Potential Role of Distributed Facility-Scale Energy Storage Technologies in Managing Utility-Scale Power Demands

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Abstract

The growth of grid-connected renewable electricity sources and distributed generation is creating a rapidly emerging market for the deployment of energy storage technologies. To date, much of the focus has been on utility-scale projects. However, facility and campus-scale energy storage show promise for managing grid impacts, allowing the continued expansion of reliance on solar photovoltaic, wind, and other distributed sources.

The paper's authors are currently investigating facility/campus-scale energy storage for efficiency program administrators and recently completed a storage technology research report for an international consortium of utilities. This work has identified promising avenues for distributed storage. Currently, facility-scale storage has three primary uses:

1. Power quality – The monitoring and regulation of voltage fluctuations, frequency disruptions, and harmonic distortions (computer networks and data centers).
2. Bridging power – Short-term power supply for critical demands, often used to cover time periods while emergency generators power up. Uninterruptible power supplies often perform these duties.
3. Energy management – Energy storage on a scale to support a facility/campus for extended periods of time. These systems can be responsive to utility demand programs and time-of-use rates to cut peak demand costs.

All three of these uses inform the development of strategies for utilizing distributed storage for the successful integration of expanding renewable energy generation.

This paper will present the technical properties of current storage systems, including flywheel, compressed air, various battery technologies, etc. The technical and market barriers associated with distributed storage, along with proposed paths for resolving said barriers, will also be discussed.

Introduction

Facility and campus-scale energy storage are promising components for managing grid impacts associated with the expansion of distributed generation, such as solar photovoltaic and wind power, which produce variable and somewhat unpredictable output. Although utility-scale projects remain a major focus, smaller scale projects, properly deployed, have the potential to perform significant load management duties allowing power grids to better absorb variable and/or intermittent generation. Due to the size and roles of their host, facility-scale energy storage is typically focused on managing power quality while utility-scale energy storage is naturally oriented towards managing energy.

Grid-scale energy storage developed originally in the mid-1920s primarily in the form of pumped hydro storage facilities in order to provide a means of shifting electricity from periods of low demand to periods of high demand (Denholm, et al. Jan 2010). During the 1990s the Sandia National Laboratory (SNL) identified and documented thirteen ways that utilities could use energy storage. During the summer of 2013, SNL released an updated electricity storage handbook detailing additional uses for energy storage; specifically, customer energy management applications, such as demand charge reduction (Denholm, et al. Jan 2010).

Facility scale energy storage shows promise for managing grid quality issues from the customer side of the distribution network by providing temporary power needs while generators come online, allowing participation in peak demand reduction programs, shifting peak load to off-peak periods, and shaving customer load spikes. Currently, facility scale systems typically range in capacity from 100 kW up to several MW. Frequency regulation and bridging storage are designed with discharge times in the order of minutes, while energy management storage systems are designed with discharge times upwards of six hours. (Denholm, et al. Jan 2010).

While there are several types of technologies that support facility-scale energy storage, batteries are the most mature and readily available option for smaller applications. There are promising technologies suitable for facility-scale energy storage, ranging from pure research endeavors, such as iron-chromium chemistries, to mature commercial technologies such as lead-acid batteries. This work focusses on battery chemistries and flywheel technologies that have been demonstrated successfully and/or are currently under later-stage development.

Key Terminology

In order to understand the functions that energy storage serves for utilities and their customers, certain key parameters need to be defined. Energy storage uses can generally be categorized in one of three groups – power quality, bridging power, or energy management – that describe a sliding scale of increasing discharge time. Discharge time is defined as the amount of time that a battery can maintain its rate power output.

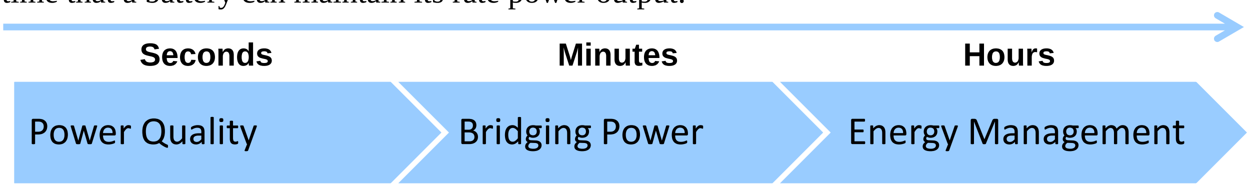

Figure 1. Use Categories on the Discharge Time Spectrum

Uses for energy storage can be categorized more generally as either a power (demand) application or an energy (consumption) application. A power application refers to a system that is primarily designed to provide power to the system over a short time period in order to reduce momentary peak power levels and/or to improve facility power quality. Energy applications are designed primarily to shift energy usage from one time period to another. Like the sliding scale of discharge times, there is a sliding scale between power and energy applications with a broad grey area in between. This is often the target area for facility-scale energy storage because it allows the system to be used for multiple applications, which adds value.

Table1 contains key terminology and their definitions. Important implications are also provided for additional insight as considerations.

Table 1. Key Terminology and Considerations.

Term	Definition	Considerations
Power capacity	The kilowatt (kW) output that the equipment is safely rated to operate at.	Operating at higher power outputs, relative to the battery's rate power, can cause excessive wear and tear.
Energy capacity	The total amount of energy (kWh) that the storage can hold.	The technical energy capacity of the battery will be greater than the rated energy capacity because of efficiency losses and depth of discharge limitations (see below)[1].
Discharge time	The maximum duration (h) over which a battery can discharge at its rated power.	Discharge time is derived from the ratio of the battery's energy capacity to its power capacity[2].
Cycle life	The number of charge and discharge cycles that a battery can sustain within its EUL.	Cycle life varies widely by technology, as well as within each technology by manufacturing quality and operating conditions.
Depth of discharge (DOD)	The percentage of a battery's technical energy capacity that has been discharged.	Batteries are rated for DOD, cycling beyond which will significantly reduce cycle life for certain battery types.
Degradation	The rate of reduction in a battery's technical energy capacity over time or use.	Most batteries are considered at the end of their expected useful lifetime (EUL) when they reach 80% of their original energy capacity[3]. Degradation rates are impacted by battery design and operational factors including the DOD, operating temperature, the rate of discharge.
Self-discharge rate	The rate at which batteries lose energy while idle	Typically 2% to 5% of the total system capacity per month for li-ion and lead acid batteries, and in part defines the shelve life of the battery.
Round trip efficiency	The ratio of usable energy to the energy required to charge the battery.	Round trip efficiency is a measure of the charging and inverter losses.
Power density	The battery's power output (kW) per unit of the device's physical volume.	Power density defines how much space a battery will need for a given power rating.
Energy density	The battery's energy capacity per unit volume.	Energy density defines how much space a battery will require for a given energy capacity.

[1] Technical energy capacity × maximum DOD = energy capacity

[2] It is useful to compare batteries to a car in order to understand these terms. If power capacity is the "top speed" of the battery, energy capacity is the "gas tank" and discharge time is the "miles" that the battery system can travel without refueling.

[3] Most batteries lose energy capacity in a linear fashion up until they reach a critical point, called rollover. At this point degradation gathers speed rapidly and the battery soon becomes inoperable. Not all batteries have a rollover point.

Facility Applications for Energy Storage

Energy storage equipment is expensive and by nature of business, without incentives, facility owners are only likely to install the equipment if it is a necessity or provides tangible value. An example is the installation of uninterruptible power supplies (UPS) to keep critical systems operating during short duration power disruptions. Also, incentives through rate structures, or other mechanisms, can create value streams that outweigh the capital cost and risks associated with installing the storage system. Incentives for “peak shaving” and “load shifting” are prime examples. It is common for a battery system to be designed with the intent of serving multiple uses, thereby increasing its value to the customer (Akhil, et al. 2013). The facility uses for energy storage that will be covered in this paper are:

1. Resiliency and power quality
2. Demand charge reduction
3. Demand response
4. Retail energy time shift
5. Renewables integration

These end uses are covered by the most recent version of the DOE Energy Storage Handbook and are supported by multiple interviews with energy storage systems providers. Their comparative parameters are summarized in Table 2.

Table 2. Facility use characteristics

Facility use	Power capacity	Discharge time	Frequency of use
Resiliency and power quality	100 kW to 1 MW	15 minutes or less	Variable; as needed
Demand charge reduction	50 kW to 1 MW	1 to 4 hours	Daily
Demand response	50 kW to 1 MW	4 to 6 hours	Infrequent
Energy cost savings	100 kW to 1 MW	1 to 6 hours	Daily
Renewables integration	100 kW to 500 MW	up to several hours	Daily

Sources: (APS Physics 2007) (Erey 2010) (Akhil, et al. 2013)

Energy storage has key niche applications for certain types of facilities and businesses. The most widely deployed facility-scale application is UPS because it is an essential component of maintaining the resiliency of critical loads. Non-resiliency applications such as demand response, peak demand shaving, and energy management provide the value streams because of their importance to utility grid power management (Akhil, et al. 2013) (Rastler 2010) (Denholm, et al. Jan 2010).

Resiliency and Power Quality

Resiliency encompasses both power quality and dependability. Energy storage systems that correct poor-quality power protect facility equipment such as compressors or servers, and those that provide dependable power prevent loss of business from equipment downtime. Some examples of poor quality power that can be corrected with an energy storage system are variations in voltage and harmonic distortions. Dependability power solutions are installed when even short duration interruptions of service are unacceptable to equipment or business operations.

UPSs and are the most common type of energy storage device used to address power quality and resiliency issues. As a result, they have become the second most important storage technology, measured in total installed kW of capacity, after utility scale bulk storage (PV Magazine 2014).

Although data centers are the primary businesses purchasing UPS systems, other building types also utilize UPSs, such as the following:

- Telecommunications – Telecommunications companies utilize equipment that is very similar to data centers and is also vulnerable to low quality power.
- Industrial – Certain industrial processes may result in costly loss of product if there are power interruptions, even if on a very short time scale.
- Emergency response – 911 call centers are often required by law to have a UPS system.
- Medical – Hospitals may have certain types of equipment that cannot have power interruptions.

Demand Charge Reduction

Utilities assess demand charges ($/kW) to commercial and industrial facilities based typically on their highest monthly demand. The technical parameters of an energy storage system designed to provide demand charge reduction are:

The interviews ERS conducted revealed that businesses who design and provide energy storage system services report simple paybacks of 5 to 7 years for facilities that have more than 50% of their electric charges from markets with high demand charges such as New York City. By targeting facilities with intermittent and large demand spikes, energy storage systems can yield large savings with a low-energy, and thus low-cost, solution. Energy storage system suppliers unanimously indicated in interviews that demand-charge savings are the primary driving force of nearly all non-UPS facility-scale storage projects.

Demand Response

Demand response (DR) programs offer to pay for reliable demand reduction during certain peak demand windows. These peak demand "events" typically occur during summer peak usage hours with each event lasting four hours or longer. Utilities sponsor DR programs to alleviate loads on the electricity distribution system during periods of anticipated heavy use.

The lucrativeness of demand response events varies by region but in some cases it may be worthwhile for a facility to expand a relatively low-energy battery system to accommodate local demand response requirements.

Layering demand response revenues with demand-charge reduction is not especially popular because it has two consequences: (1) it will typically require a battery with double the discharge duration (and cost) of one employing only a peak-clipping strategy and (2) by partaking of both peak clipping and demand response a customer is incapable of realizing the full potential of either value stream due to competing claims on the same discharge capacity.

Retail energy time shift

Retail energy time shift refers to storing energy during periods when the retail electric price ($/kWh) is low and using the stored energy when prices are high. Businesses can employ this strategy to reduce their electricity bills where the local utilities apply time-of-use pricing.

Energy systems providers report that retail energy time shift is not a particularly lucrative value stream for businesses and thus does not drive projects except in places where there is a large peak off-peak spread for energy prices (e.g., Hawaii). However, it is usually included as a follow-on value stream for demand-based strategies.

Renewables Integration

The integration of battery storage capacity with renewable energy generation projects, primarily for wind and solar, is an increasingly common practice that provides important benefits to the grid. The fast response time of batteries presents an attractive pairing with renewables; batteries can provide frequency regulation services and can bridge gaps in production due to the intermittency of renewables, while also time shifting the load to periods of high demand. These functions are critical to enabling renewable energy generation integration with the grid.

While energy storage plays critical support for utility scale renewables integration with the grid, usually the grid itself supports renewable generation installed at customer locations. As distributed renewable generation increases, electrical energy storage will play a critical role in supporting the grid regardless of installation at facilities or utilities.

Energy Storage Technologies

A broad variety of technologies is being developed for energy storage uses at all scales but currently the only mature technologies that suit the commercial needs for businesses are the following:

- Lead acid and emerging advanced lead acid chemistries
- Lithium ion
- Sodium sulfur batteries
- Flywheels

While other technologies may be available, facilities are not likely to install such systems because of the risks of investing in an immature technology. Emerging battery technologies that are poised to enter the energy storage market in the near future include:

- Flow
- Sodium nickel chloride (ZEBRA)

Table 3 presents compiled summary technical parameters for each of the technologies reviewed as compiled by the author from published literature and battery manufacturer interviews.

Table 3. Comparison of Battery Technical Parameters

Market	Battery Type	Installed Energy Cost ($/kWh)		Roundtrip Efficiency (%)	Useful Life	
		Suburban (Outdoors)	Urban (Indoors)		Cycle Life	Expected Lifetime (Years)
Commercial Technologies	Lead acid	$700 – $1,000	$800 – $1,200	70% – 80%	500 – 1,500	3 – 5
	Lithium ion	$1,000 – $2,000	$1,500 – $2,500	85% – 98%	2,000 – 5,000	10 – 15
	Sodium sulfur (salt)	$750 – $900	$1,000 – $2,000	70% – 80%	2,500 – 4,500	10 – 15
	Nickel cadmium	$1,000 – $1,500	$1,250 – $2,000	60% – 70%	800 – 3,500	15 – 20
Near Commercial	Advanced lead acid	$900 – $1,500	$1,200 – $1,800	80% – 90%	1,000 – 2,000	5 – 7
	Vanadium redox (flow)	$1,000 – $1,500	$1,500 – $2,000	60% – 70%	10,000+	5 – 15
	Zinc bromine (flow)	$750 – $1,250	$1,250 – $1,750	60% – 70%	10,000+	5 – 10
	Sodium nickel chloride	$1,000 – $1,500	$1,300 – $1,800	80% – 90%	2,500 – 4,500	10 – 15

Source: Akhil, et al. 2013, Chen, et al. 2008, Poullikkas 2013, Rastler 2010, and Interviews: 2014

Lead Acid

Lead acid batteries are the most mature battery technology available and are used in vehicles worldwide (Akhil, et al. 2013). They are typically the standard by which other batteries are measured due to their reliability and low cost, but offer only mediocre energy or power density and lifetimes. Importantly, they are capable of only a limited DOD; full discharges will damage the battery and shorten its life.

Lead acid batteries are manufactured worldwide by hundreds of manufacturers and will continue to be a staple of energy storage projects worldwide until capital costs of other technologies can overcome those offered by lead acid.

Advantages

- They are usually the cheapest option per installed kW and kWh.
- They are highly modular.

Disadvantages

- Their cycle life is low under even optimal conditions (<2,000), and under high temperatures or especially deep depth of discharges (>50%), their cycle life is greatly reduced down to as few as 500 cycles.
- Lead acid batteries are comparatively heavy, restricting their usage due to practical and building code considerations.

Advanced Lead Acid

Advanced lead acid batteries employ carbon in different ways such as enhance surface area in the cathodes to improve lifetime and DOD over traditional lead acid batteries. Companies researching this type of battery include Ecoult/EastPenn, Axion Power International, Xtreme Power, GS Yuasa, and Hitachi. Each company has its own proprietary take on the technology but they all seek to overcome the shortcomings of traditional VLA and VRLA batteries, improving the life and depth of discharge capability (Klein and Maslin 2011) (Akhil, et al. 2013).

Lithium Ion

Lithium ion batteries are typically constructed of carbon and metallic electrodes with a lithium based electrolyte. There are a variety of subtly different cell chemistries that can be used to construct these batteries that are often proprietary to a specific manufacturer.

The market for lithium ion batteries continues to grow due to their excellent energy and power densities, which makes them lighter and more compact than any other commercial battery technology. They are also capable of full discharge/charge cycles without reducing the battery's cycle life, unlike lead acid batteries. They will also typically last about twice as long as lead acid batteries, when operated under optimal conditions. However, the lithium ion batteries currently cost two to three times more than lead acid batteries on a power capacity basis. These characteristics give them an edge in situations where space or weight might be valued over capital cost such as small businesses without much space to spare.

They are expected to come down in cost in the coming years, which makes them a likely candidate to become the dominant battery technology in the medium term.

Advantages

- They have a long cycle life that is not affected by DOD.
- They can be arranged to provide the same voltages as lead acid for easy retrofits.
- They have a high energy/power density.

Disadvantages

- They are costly.
- They have the potential to cause runaway fires if not properly maintained and operated.

Sodium Sulfur (NaS)

Sodium sulfur batteries were developed in the 1980s by NGK Insulators, LTD., the primary manufacturer of the technology, and Tokyo Electric Power Co. Except for requiring very high operating temperatures, NaS batteries have favorable characteristics for larger scale energy storage such as low cost and high energy capacity. They are often referred to as molten salt batteries because during operation they are composed of molten sulfur and liquid sodium separated by a ceramic electrolyte (Akhil, et al. 2013).

Sodium sulfur batteries are primarily installed in controlled outdoor locations because of their high operating temperatures and are used typically in energy arbitrage or other uses that require long discharge times (Poullikkas 2013). They have not been looked upon favorably by building- and fire-code departments, limiting their urban-scale deployment potential. For certain niche applications requiring lengthy discharge duration and with ample outdoor space, this technology may offer a feasible solution.

Advantages

- They have a long shelf life.
- They are well-suited to applications requiring long discharge durations.

Disadvantages

- They require high operating temperatures.
- There are very few manufacturers of this technology.
- Space and weight intensive

Flywheels

Flywheels are commercially available on a small scale and several companies including Beacon Power, POWER*THRU*, and VYCON offer them. Because of their short discharge durations, flywheels are appropriate to power quality and uninterruptible power supply solutions, but are not suitable for longer duration energy management functions. Sizes range from 25 kW for the Beacon system up to 300 kW for a single flywheel, and they can be linked in parallel to accommodate much larger energy storage (VYCON 2010) (Beacon Power 2012). Larger compound systems are currently in the demo phase and can satisfy low-end bridging power solutions, but the inherent properties of flywheels are more suitable for power quality applications (Akhil, et al. 2013).

Sodium Nickel Chloride (ZEBRA)

Sodium nickel chloride – also called ZEBRA – batteries are high temperature (300+°C) batteries that are similar to sodium sulfur technologies, but with improved safety characteristics. Only two manufacturers are making these batteries currently, but they have long lifetimes and generally better performance characteristics than traditional lead acid batteries without some of the safety concerns associated with sodium sulfur batteries (Akhil, et al. 2013).

Flow Batteries – Vanadium Redox (VRB) and Zinc Bromine (ZnBr)

Flow batteries rely on a liquid electrolyte which flows through the battery. This means that the energy storage capacity of the battery can be increased or decreased just by adding or removing electrolyte. This allows the energy storage capacity to be decoupled from the number of cells. Sumitomo Electric Industries is the main investor in vanadium flow batteries and ZBB Energy Corporation is the primary manufacturers of zinc bromine batteries. Both have package options available for purchase, though the number of deployments is limited (Klein and Maslin 2011).

The pumps, storage and piping required by a flow battery reduces its overall energy density (as they require expanded footprints for the equipment), and entail operations and maintenance responsibilities that exceed those of other technologies. On the other hand, although systems are not easily obtainable yet, predictions look more cost-effective for long discharge times (>6 hours) than conventional batteries. Vanadium batteries in particular, have potential for very long shelf and cycle life, but zinc bromine batteries are slightly cheaper (Rastler 2010) (Chen, et al. 2008).

Technical and Market Barriers

There are a number of technical and market barriers preventing energy storage systems from reaching their full distribution potential. Over and above specific technical barriers, there is general consensus among energy storage system designers that one of the biggest issues is a negative public perception toward energy storage technologies. Generally, there is poor understanding of energy storage systems among building owners, how they operate, and the value streams they can provide.

Performance Barriers

The two primary technical barriers for batteries at this time are:

1. Limited cycle life and equipment shelf lives
2. High costs of systems

It is essential for battery systems to improve lifetimes and provide better warranties in order to gain general acceptance for their uses. Lead acid battery's lifetime of 3-5 years is very short compared to most commercial equipment EULs. Progress is being made on this front primarily in the form of flow batteries and lithium ion chemistries, which boast lifetimes of 7-10 years and up, but suffer from high cost and lack of maturity.

Longer cycle and shelf lives will increase the value of batteries but the primary barrier to their widespread use is still capital cost and lack of clearly defined value streams. Increasing demand charges and demand management programs, such as New York City's that provide incentives of $2,100/kW for battery storage, improve the simple paybacks of projects. But, facilities must still have high demand charges to provide a revenue stream that supports the current costs of installation for any energy storage system.

Material Hazards

All battery technologies come with some inherent risks to human and environmental health and safety. They typically contain toxic chemicals in their electrolytes and have the potential to overheat, catch fire, and explode.

For commercially available storage technologies the risks are generally well understood and can largely be mitigated through appropriate installation and fire protection, rendering batteries safe even in the urban environment. Many energy storage systems come packaged in 20 or 40 foot containers. These are durable, weather proof and secure enough to allow for outdoor installations.

Construction and Siting Barriers

There are two primary construction complexities when installing with facility-scale battery storage systems:

1. Size – The facility needs to find suitable unoccupied, dry space – which can be sizable depending on the technology – to designate to these systems for permanent siting.
2. Weight – Most batteries are quite heavy due to the nature of the materials they are constructed from. For instance, sodium sulfur batteries weigh upwards of 500 pounds per square foot, which is about five times the design standard of a normal commercial floor.

Often the best location for these systems is outside on a poured concrete slab and sheltered by a shipping container. As a result many companies package their energy storage systems in this way.

Permitting and Codes

Local building fire codes and the construction permitting are a significant hindrance to the adoption of specific technologies such as in New York City, which currently has incorporated in its fire code only lead acid, and very recently, lithium ion batteries (Cerveny 2014). Other than overcoming economic hurdles, this presents the largest barrier. Code requirements for battery storage are designed to ensure safe installation and operation of battery systems. Their focus is on safety precautions to mitigate impacts of spills, fires, natural disasters, and unauthorized access.

Summary

No one battery has proven superior at this point and different battery systems continue to be most suitable for different applications. This competitive market supports a broad range of technologies in development and it is unclear if the environment will stay competitive or yield to a dominant brand or chemistry.

Energy storage technologies address specific needs for both facility owners and electrical generation/distribution managers. Facility owners can utilize storage to provide resiliency for critical operations, thereby protecting profitability. Utilities and electric system operators increasingly need storage capability to efficiently incorporate renewable and other variable generation sources. By offering electric customers the right mix of financial incentives and power management education, the combined value streams will support the growth of both campus and facility scale storage systems.

References

Akhil, A, et al. *DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA.* Livermore, CA: Sandia National Laboratories, 2013.

APS Physics. *Challenges of Energy Storage Technologies.* Ridge NY: APS, 2007.

Beacon Power. *About Flywheel Energy Storage.* 2012. www.beaconpower.com/products/about-flywheels.asp (accessed 2 2014).

Bradbury, Kyle. "Energy Storage Technology Review." August 2010.

Cerveny, J. *NY Best.* March 21, 2014. http://www.ny-best.org/blog-entry/update-nyc-%E2%80%93-commissioner%E2%80%99s-forum-energy-storage-new-york-city-department-buildings (accessed 5 2014).

Chen, Haisheng, Thang Cong, Wei Yang, and et al. "Progress in Electrical Energy Storage System: A Critical Review." *Progress in Natural Science* (S) 2009, no. 19 (2008): 291-312.

Denholm, P, E Ela, B Kirby, and M Milligan. *The Role of Energy Storage with Renewable Electricity Generation.* NREL - DOE, Jan 2010.

Erey, GC Jim. *Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide.* Albuquerque, NM: US DOE, 2010.

Interviews: Green Energy Networks, ZBB, Eagle Picher, Demand Energy, GE Energy Storage, Imergy Power, Convergent, GSA, BYD, interview by Energy & Resource Solutions. *Technology overview, costs and trends* (2014).

Kamath, Haresh. "II. Energy Storage Technology Overview." 2010. http://www.netl.doe.gov/technologies/coalpower/fuelcells/seca/tutorial/TutorialII_files/TutorialII.pdf (accessed 07 11, 2012).

Klein, A, and T Maslin. *US Utility Scale Battery Storage Market Surges Forward.* IHS Emerging Energy Research, Sept 2011.

Poullikkas, Andreas. *A comparative overview of large-scale battery systems for electricity storage.* Academic, Nicosia, Cyprus: Renewable and Sustainable Energy Reviews, August 2013.

PV Magazine. *Trends in energy storage markets.* 2014. http://www.pv-magazine.com/archive/articles/beitrag/trends-in-energy-storage-markets-_100010780/86/?tx_ttnews%5BbackCat%5D=217&cHash=dc05a369712231e32e05bd86fb4a8c86 (accessed 2 2014).

Rastler, D. *Electricity Energy Storage Technology Options.* Palo Alto, CA: Electric Power Research Institute, 2010.

VYCON. *UPS/Power Quality.* 2010. http://www.vyconenergy.com/pq/ups.htm.