Turning Backup Power Reserves Into Green Revenue

A Technical Paper prepared for SCTE by

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1. Introduction

Hybrid supercapacitors have several unique technical properties, such as a significantly greater number of charging/discharging cycles than other energy storage devices. As a result, communications service providers (CSPs) adopting this technology for standby power operations can generate revenue by participating in regional energy imbalance markets (EIMs) and pursuing energy arbitrage options offered by their local utilities. The utility industry created the EIM concept a few years ago to establish an energy bid market for providing flexible power reserves that can be tapped as needed to meet customers' energy demands. This overview paper will explain how cable operators and other CSPs can adopt hybrid supercapacitors to create new revenue sources and curb carbon emissions by selling their idle energy back to utility companies — without compromising or interrupting their own backup power operations.

For the most part, battery-based energy storage has not fundamentally changed over the past 2,000 years. In 1938, an excavation team working in southern Iraq unearthed what is now commonly known as the Babylon Battery, an ancient energy source that was essentially an archetype for the batteries that now provide backup power in telecommunications facilities. Like today's lead-acid batteries, the roughly five-inch clay pots found in Iraq featured copper cylinders with encased iron rods, as well as liquid that apparently once acted as an electrolyte.

Figure 1 - Electrochemical Energy Storage Dates Back To Ancient Babylon

Although legacy electrochemical batteries will likely extend their millennium-plus reign for decades to come, the recent introduction of energy storage devices that also incorporate an electrostatic, or non-electrochemical, design offers telecommunications providers, datacenters and other companies the ability to significantly improve the performance and safety of their backup electric power operations. Known as hybrid supercapacitors, these new storage devices also offer telecom providers the ability to create a promising revenue source via participation in energy arbitrage applications and the EIM, the focus of this paper.

The utility industry created regional energy market mechanisms such as the EIM to take advantage of reserve power that can be tapped as needed to meet their customers' ever-changing needs. Given the distributed nature of their facilities, telecom providers that adopt hybrid supercapacitors as an energy source could be prime contributors to the EIM, enabling them to generate new revenue.

This paper seeks to provide readers with an introduction to hybrid supercapacitor technology, an understanding of how hybrid supercapacitors differ from traditional energy storage media and an appreciation of how those distinguishing characteristics enhance the technology's ability to generate revenue for service providers through the sale of their idle stored energy. The paper also seeks to educate readers about today's electric power grid and how it functions to meet the nation's energy demands, as well as the critical role that new energy storage media such as hybrid supercapacitors can play in meeting those demands.

2. Defining Hybrid Supercapacitors

Standard supercapacitors are a non-chemical type of energy storage device. Known technically as electric double-layer capacitors (EDLCs), supercapacitors leverage the electrostatic effects that occur between two activated-carbon electrodes with high specific surface areas per volume. The electrodes are immersed in an electrolyte, and a separator between the electrodes is used.

Hybrid supercapacitors are next-generation variants of these devices. Unlike standard supercapacitors, hybrid supercapacitors are partly electrostatic and partly electrochemical in nature and store and release energy through the reversible adsorption and desorption of chemical ions at the interface between electrode materials and electrolytes.

In other words, hybrid supercapacitors leverage both chemical and electrostatic processes to store electric power. Thanks to this ability, they blend the best attributes of both battery and capacitor to create a novel storage medium particularly suited for energy arbitrage applications.

Unlike purely electrochemical devices, hybrid supercapacitors are asymmetrical devices, constructed of a lithium-doped graphite anode and an EDLC-activated carbon cathode. As a result, their charging and discharging cycles are electrostatic processes, free of chemical reactions. This difference eliminates the potential for leakage of harmful chemicals or for thermal runaway, which can cause dangerous, difficult-to-extinguish fires.

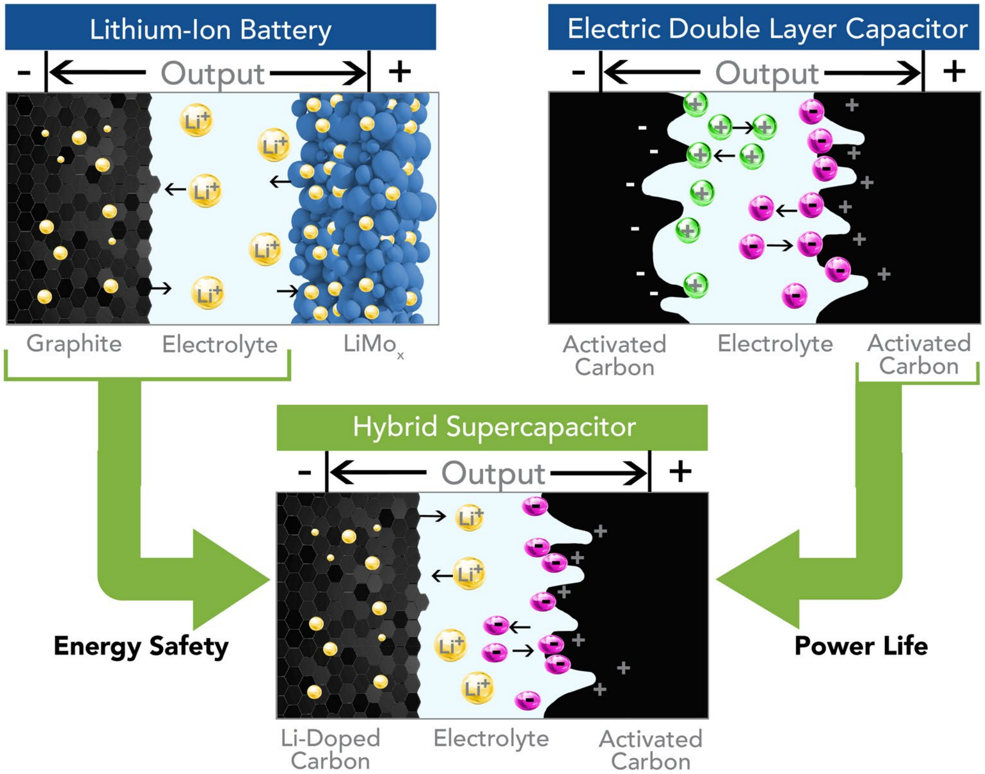

Figure 2 - Anatomy Of A Hybrid Supercapacitor

What makes hybrid supercapacitors different from both standard supercapacitors and older, lead-acid and lithium-ion batteries is that they link two energy-storage mechanisms in parallel, combining lithium-ion technology and EDLC construction in one neat package. Due to this unique combination, hybrid supercapacitors bring together the high-power capabilities of capacitors with the high-energy storage capabilities of batteries. This means that hybrid supercapacitors can safely and efficiently deliver improved performance over chemical-based storage media, as well as offer energy arbitrage applications that can generate revenue in an environmentally friendly way.

Delving into the specifics, hybrid supercapacitors feature a vastly greater number of charging/discharging cycles than conventional batteries. Hybrid supercapacitors have an expected lifespan of roughly 20,000 to 50,000 charging/discharging cycles, based on full depth of discharge (DoD), a key energy storage metric, at 25 degrees Celsius. That's significantly more than the roughly 300 lifecycles of lead-acid batteries, based on less than 80% DoD at 25 degrees Celsius.

The relatively low charging rate of lead-acid batteries renders them essentially ineligible for energy arbitrage. Looking at the middle range, lithium-ion batteries, with a lifespan of no more than 5,000 cycles for a 90% DoD at 25 degrees Celsius, are currently deployed in some energy arbitrage environments. However, their lifespan pales in comparison to that of hybrid supercapacitors and they are prone to thermal runaway.

Furthermore, nearly 100% of a hybrid supercapacitor's storage capacity is usable energy because its self-discharge is mitigated by the lithium doping of the device's anode and cathode. That's due to the addition of the electrochemical component to the EDLC, which has notorious self-discharge issues because it is purely electrostatic. As a result, hybrid supercapacitors can maintain their voltage over much longer stretches of time than other energy storage media without the need to connect to a charging source.

In addition, hybrid supercapacitors are significantly safer to operate and maintain than lithium-ion or lead-acid batteries for two main reasons. First, hybrid supercapacitors do not overheat like the other energy storage devices because they are very efficient, achieving greater than 97% energy efficiency, because of their electrostatic component.

Second, hybrid supercapacitors do not run the same risk of "thermal runaway" as the other main energy storage media. Although they do contain electrolytes that could leak if damaged and are flammable, a puncture or other damage would not generate enough internal heat to generate the chemical process of thermal runaway. That's because hybrid supercapacitors have a different chemical composition than lead-acid and lithium-ion batteries, the chemical composition does not contain oxygen or metal oxide. A hybrid supercapacitor efficiency cannot generate enough heat to break down the internal chemical composition. Hybrid supercapacitor efficiency combined with the lack of metal oxides eliminates its ability to feed fires or propagate combustion associated with "thermal runaway" that's inherent with traditional lithium-ion batteries available today.

Table 1 - Comparing Energy Storage Technologies

	Hybrid Supercapacitors	Lithium-Based Batteries	Lead-Acid Batteries
Type	Electrostatic & Electrochemical	Electrochemical	Electrochemical
Lifecycles	20,000–50,000	5,000	300
Depth of Discharge	100%	80-90%	60-80%

3. Understanding EIMs And Energy Buybacks

As noted in the paper's introduction, EIMs are regional energy marketplaces that the utility industry created to supply electricity generation and transmission services whenever and wherever they are required. The idea is to provide flexible energy reserves to power companies, reserves that can be tapped at any time to meet customers' ever-changing energy needs. The figure below depicts the common components in today's energy grid, as well as its distribution infrastructure.

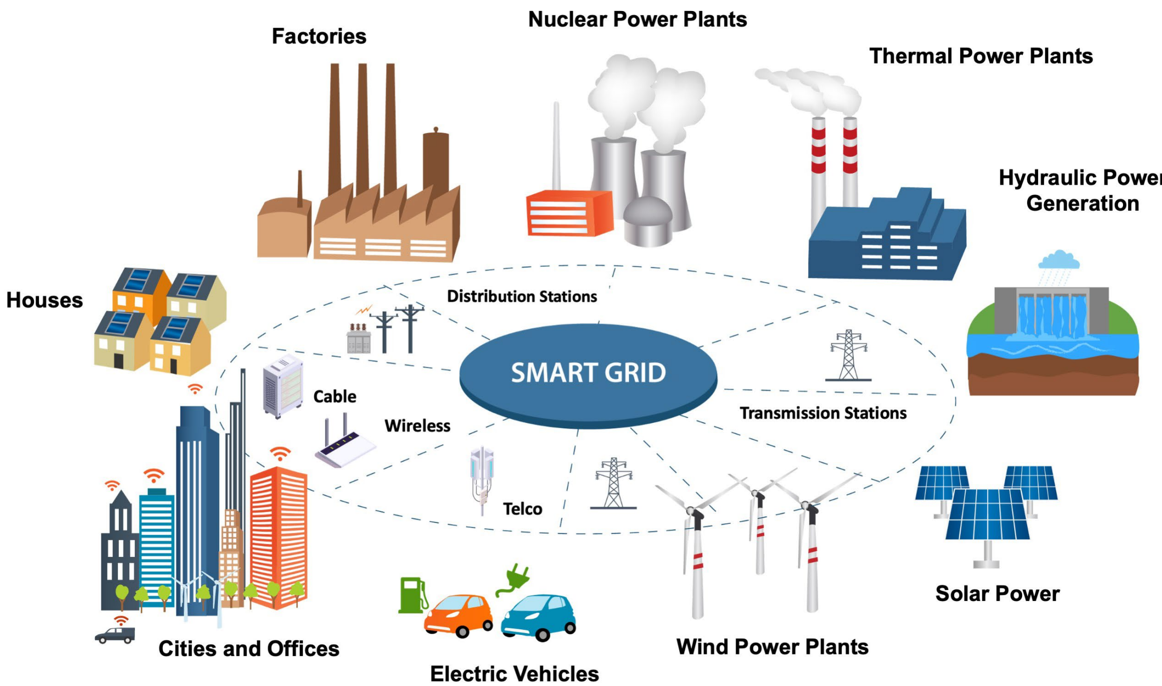

Figure 3 - Mapping Today's Energy Grid

EIM participants may come from multiple public authority areas and utility territories. Combining in this way increases the economic efficiency of the nation's power system and enables centralized, automated and region-wide power generation and distribution. As more utilities join an EIM and boost its size, range and diversity, the benefits increase for all customers.

Currently, most utilities rely predominantly on legacy power plants, which burn heavily polluting fossil fuels, to meet peak customer demand for electricity because they have few other energy sources available to tap. These reserve resources, known as spinning reserves, are significant contributors to the planet's growing carbon footprint and accelerating global warming. As more of the planet experiences extra-hot temperatures of the type seen in summer 2023, what was "peak" demand yesterday becomes tomorrow's "normal" high level of demand.

But hybrid supercapacitors could start addressing that problem. Thanks to their unique features, as detailed earlier, hybrid supercapacitors could help utilities meet their customers' energy needs by filling the gap more efficiently and economically, and in a more environmentally sustainable way, than current energy storage solutions, many of which are still reliant on fossil fuels. Hybrid supercapacitors can also be managed to contribute energy reserves to the EIM without interfering with their own backup power responsibilities. Thus, they could enable CSPs to engage in energy arbitrage without compromising their ability to maintain continuous operations.

To qualify as ancillary energy suppliers, entities must have a megawatt-hour or more of electricity available to dispatch to the power grid to meet the needs of the regional energy imbalance market. Telecom providers can easily satisfy this requirement by taking advantage of the power of hybrid supercapacitors.

Benefits like these make hybrid supercapacitors strong candidates for enabling the sale of excess, renewable electrical power back to an EIM and the overall energy grid. In other words, hybrid supercapacitors can leverage their unique electricity supply capabilities to produce potentially substantial new revenues for telecom providers — while also lowering carbon emissions to preserve the earth's health.

4. Telecommunications Providers And The EIM: A Near-Perfect Match

Telecommunications providers can generate more revenue by taking part in energy arbitrage markets and the EIM. Apart from the other factors already cited, the revenue potential is due in large part to the highly distributed nature of telecommunications facilities, which typically are scattered throughout regions, cities and even neighborhoods. Such a pattern lines up neatly with the distributed nature of the nation's energy distribution grid.

A national wireless provider like AT&T®, for example, might operate thousands or even tens of thousands of cell towers across the country. As a result, an operator of that size is likely to have thousands of megawatt-hours of untapped energy capacity waiting to be used across its various sites.

Because most major telecom operators rely heavily on conventional lead-acid batteries in their transmission facilities, all that stored electricity can only be used to provide backup power in the event of a utility blackout or service interruption. As noted earlier, lead-acid batteries have limited charging/discharging cycles and thus are not able to support energy arbitrage applications.

Even if facilities can leverage the newer lithium-ion batteries for power, that's still far from an ideal solution for participating in the EIM. That's because lithium-ion batteries also lack the extended charging/discharging cycle lives of hybrid supercapacitors. Thus, lithium-ion batteries degrade much faster, which means they would need to be replaced much sooner than hybrid supercapacitors.

Hybrid supercapacitors offer one other key benefit. Unlike other energy storage solutions, they can ramp up quickly to respond to sudden spikes in electricity demand. That attribute makes them well suited to take advantage of ongoing price changes in the real-time energy markets as electricity demand fluctuates throughout the day, week, month or season.

Note: AT&T is the registered trademark of AT&T Properties, L.P.

5. How Energy Arbitrage Works

How can communications service providers make money by having more energy than they need to power their own facilities? They can take a page out of the existing energy arbitrage business, building up their energy reserves and then selling them to power companies at the right time, netting a healthy profit on their stored electricity.

Fundamentally, energy arbitrage is defined by the stock market's tried-and-true maxim of buying low and selling high. In the case of power, this can be carried out by leveraging a time-of-use (TOU) rate structure, wherein the utility penalizes the use of power during peak demand hours and rewards power consumption during off-peak hours through the prices it sets for each. With the help of hybrid supercapacitors, telecom providers can continue operations as usual but choose when to dispatch and recharge their energy capacity. Telecoms who participate in TOU can also take advantage of significant savings reducing their overall energy cost while playing a productive role aiding the utilities during high-demand hours.

Not surprisingly, providers should generally seek to sell their stored energy when electricity rates rise to their highest levels and replenish their supplies when energy rates sink to their lowest levels. Because energy rates can vary widely over the course of a day or even just a few hours, such timing is critical to success. For example, as depicted in the figure below, wholesale energy rates may drop to as low as 5 cents per kilowatt-hour (kWh) during the super off-peak hours late at night and then rise as high as 25 cents per kWh during the peak demand periods of late afternoon and early evening.

Fortunately, no elaborate calculations are required to carry out this strategy. That's because energy arbitrage is based on published utility TOU rates so it can be calculated quite easily in advance and requires no additional equipment to participate. It is simply a matter of setting the rectifiers to operate on the power grid during low-rate periods and then off the grid during high-rate periods, thereby taking advantage of the excess energy that was stored internally during the off-peak hours.

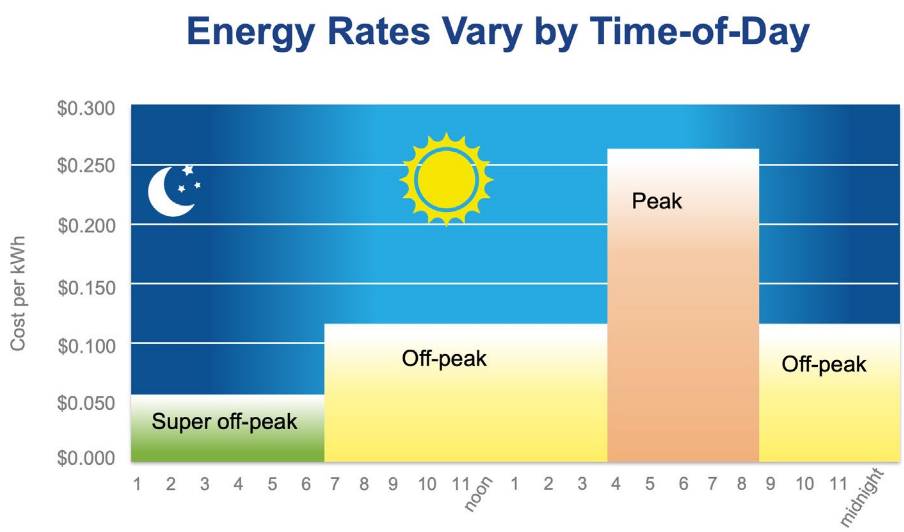

Figure 4 - How Energy Rates Vary

By engaging in energy arbitrage, cable and other telecom providers could generate substantial revenue from an otherwise idle asset in their facilities. Plus, by replacing heavily polluting energy from fossil fuel-powered plants with clean energy stored by hybrid supercapacitors, operators could help rid the planet of some of its biggest climate-change accelerators.

To illustrate this point, the following section considers several basic energy arbitrage revenue models.

6. How Hybrid Supercapacitors Can Generate Revenue

As noted in the previous section, wholesale energy rates at different market levels vary greatly throughout the day and, at their peak levels, can greatly exceed the cost of electricity sold to consumers. Although hourly energy prices vary by both season and location, prices generally increase as the energy load increases.

So how much revenue could telecom providers generate by engaging in energy arbitrage and/or participating in the EIM with the aid of hybrid supercapacitors? Although the initial financial projections are rough, they indicate that operators could generate a return on investment (ROI) in as few as six or seven years, depending on the market in which they are participating and their supply/demand circumstances, by selling their idle stored energy back to the power grid and electric utilities.

As explained by Green Rhino Energy (www.greenrhinoenergy.com), a green-energy project developer and consultant, the greatest revenue stream would come from selling electricity back to the power grid at either a fixed rate (the TOU use case) or a variable market price (the EIM use case). Even if the telecom facility was not connected to the greater power grid, the operator would still benefit from reduced generator run-time. In addition, depending on the state or region, the service provider might be able to generate and sell renewable energy certificates or carbon emission reduction certificates to others.

If they make use of solar power to produce electricity, cable and other telecom operators could also reap revenue from a second income stream: federal and state tax benefits. These benefits include both *production* tax credits, which offer set amounts for every kilowatt-hour of solar power produced over a fixed-time period, and *investment* tax credits, which enable companies to offset some or all of their initial investment over a certain number of years against pre-tax profits. The value of the tax credits depends on the investor's overall tax capacity.

Previously, CSPs would need to install solar to realize significant tax benefits. Federal investment tax credit (ITC) has been extended to energy storage only.

7. Energy Storage Models

As noted in the previous section, wholesale energy rates at different market levels vary greatly throughout the day and, at their peak levels, can greatly exceed the cost of electricity sold to consumers. Although hourly energy prices vary by both season and location, those prices generally increase as the energy load increases.

How much revenue telecom providers generate by engaging in energy sellbacks and participating in the EIM with the aid of hybrid supercapacitors is dependent on several variables, including the available energy storage, the frequency of participation and the rate at which the energy is sold back to the utility.

The following chart provides an example of an energy sellback model that is based on a telecommunications company with 100kWh of available storage selling off all available energy storage for an hour a day, over 91 days of the year. The rate per hour is based on public information from Southern California Edison.

Table 2 - Energy Sellback Model

	Rate Per Hour	Rate Per Hour	Rate Per Hour
	\$3.79706	\$3.65744	\$0.91592
Revenue Per Day (1 hour)	\$379.70600	\$365.74400	\$91.59200
Revenue Per Year (91 days)	\$34,553.24600	\$33,282.70400	\$8,334.87200

As the chart indicates, communications providers that participate in energy sellback when rates are at their highest (\$3.80) can generate nearly \$35,000 annually by discharging energy storage for just one hour over three months of the year. Even at a rate of less than \$1, annual revenue can exceed \$8,000.

Though not the subject of this paper, telecommunications providers can also reduce energy costs by using idle energy storage to power operations when rates are at their highest and then recharging hybrid supercapacitors when energy storage costs are at their lowest. This energy savings model, known as peak shaving or Time of Use (TOU), can result in significant annual savings for telecommunications providers with a similar energy storage profile as the provider in the sellback example.

Table 3 - TOU Model

	Summer Weekdays (87)	Summer Weekends (34)	Winter Days (244)	
Peak Rate (kWh)	$0.66	$0.38	$0.60	
Non-Peak Rate (kWh)	$0.26	$0.26	$0.23	Total
Gross	$28,710.00	$16,530.00	$26,100.00	$71,340.00
Grid Recharge Cost	-$2,262.00	-$2,262.00	-$2,001.00	-$6,525.00
Net	$26,448.00	$14,268.00	$24,099.00	$64,815.00

*Peak hours per day: 5

*Non-Peak hours per day: 19

Minus the costs to recharge the energy storage modules, the telecommunications provider depicted by the TOU chart, which is also based on typical residential rate charges associated with Southern California Edison, can save nearly $65,000 annually.

8. Investment Required for EIM Participation

To engage in energy arbitrage and/or participate in the EIM, communications providers will need to invest in new equipment, ranging from the hybrid supercapacitors themselves to the supporting gear, components and software.

In addition to the hybrid supercapacitors, CSPs will need to review their current electrical solutions to support a demand response architecture.

Demand Response - Demand response is a process where the customer plays a role in the operation of the electric grid by reducing or shifting their electricity usage during peak periods in response to time-based rates or other forms of financial incentives. Alternatively, demand response can be used for balancing supply and demand. It also includes direct load control programs which provide the ability for power companies to cycle electrical loads during peak demand in exchange for a financial incentive.

Demand Response components will generally consist of the following components: metering/net metering, inverters, rectifiers, software, etc.

9. Conclusion

The energy imbalance market (EIM) offers a promising new revenue opportunity for cable operators and other telecom providers, especially as they transition to more renewable energy sources. Just as a few pioneering utilities are already doing, telecom players could draw on the idle stored energy sitting in their facilities and feed that excess power to the nation's electric power grid — all the while generating new income.

As this paper has discussed, hybrid supercapacitors offer a safe, efficient, cost-effective and environmentally sustainable way for service providers to store electric power and deliver it to the grid. By leveraging the unique qualities of hybrid supercapacitors, operators can meet their facilities' backup energy requirements AND sell their excess electricity to other players in the energy market.

Although it is difficult to project right now exactly how high the proceeds of energy arbitrage might be, the market is clearly wide open for cable operators and other telecom providers to participate by adopting hybrid supercapacitors and taking advantage of their unique energy storage capabilities. For the sake of both their business and the world's climate, the sooner they can start taking these steps, the better.

Abbreviations

CSP	communication service provider
DoD	depth of discharge
EDLC	electric double layer capacitor
EIM	energy imbalance market
ITC	Investment tax credit
kWh	kilowatt-hour
ROI	Return on Investment
SCTE	Society of Cable Telecommunications Engineers
TOU	time of use

Glossary Of Terms

Term	Definition
Depth of discharge	The percentage of an energy storage device's capacity that has been discharged relative to the device's total storage capacity.
Demand response	A process where the customer plays a role in the operation of the electric grid by reducing or shifting their electricity usage during peak periods in response to time-based rates or other forms of financial incentives.
Energy arbitrage	A system of buying power during off-peak hours when electricity grid prices are the lowest and then storing the power to sell back to the grid during peak hours when electricity prices are the highest.
Energy buybacks	A way to leverage the energy arbitrage markets by purchasing power when grid electricity prices are low for either storage or sale at a later time.
Energy imbalance market	A voluntary market that economically delivers power from participating utilities and other energy producers to balance regional energy supply and demand on a frequent, timely basis.
Hybrid supercapacitor	A variant of standard supercapacitors that combines lithium-ion technology and electric double layer capacitor construction for improved performance.
Lead-acid battery	A type of rechargeable battery that uses lead and sulfuric acid to function. The lead is submerged into the sulfuric acid to generate a controlled chemical reaction, which causes the battery to produce electricity.
Lithium-ion battery	A type of rechargeable battery that uses the reversible reduction of lithium ions to store energy. The negative electrode of a conventional

	lithium-ion cell, sometimes called the anode, is typically graphite, a form of carbon. The positive electrode, sometimes called the cathode, is typically a metal oxide.
Peak shaving	A process that proactively manages overall demand to handle short-term spikes in energy demand by lowering and smoothing out peak loads, thereby reducing the overall cost of electricity.
Supercapacitor	A type of electrochemical energy storage system that has great power density and specific capacitance, enabling the efficient release of large amounts of energy over a relatively short period of time.

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