Advanced Energy Storage (AES): Embracing New Possibilities
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Advanced RV has teamed with Volta Systems to provide our clients with light weight, high energy, integrated automotive lithium battery storage and generation without auxiliary generators. Volta Systems provide our clients with greatly expanded off-the-grid capabilities.

Exciting news about battery driven machines has been everywhere the past few years. Drones, toys, tools, gardening equipment, cars and now even semis — the list of new technology keeps growing. All of these breakthroughs are made possible by advanced energy storage.

Consumers have long dreamed of more energy storage in batteries, but until recently, there were limitations we couldn't overcome. Now the technology is progressing at such a rate that entire countries are moving away from traditional internal combustion technology.

Great Britain recently announced that it will not allow new combustion engines sales after 2050. In reaction to world-wide governmental policy changes, major auto manufacturers like Volvo have declared that they will no longer support new development of internal combustion engines, but instead focus entirely on Electric Vehicle (EV) and Plug in Hybrid Electric Vehicle (PHEV) technology.

It should be no revelation that consumers often experience a natural lag to new technology because of our natural fear of the unknown. News stories and social media posts feed on this fear and escalate the lag, like those about a single camera battery overheating and smoking from a camera bag in Florida, or an uninformed article about the availability of battery raw materials that creates undue concern.

Our society has experienced this fear before. When the automobile emerged in the early 20th century, society traveled by horse and buggy. You can imagine the confusion when the first carriage moved down the street without a horse, leading to the term "Horse-less Carriages".

Now the automobile has been a part of our society for more than 120 years. Though many consumers don't understand exactly how automobiles work, they know that automobiles are complicated machines with immense power and energy capabilities. Consumers also understand that there are risks associated with automobile fuel. We understand what happens if we don't change the oil, monitor the engine temperature, or even what to expect if an accident occurs.

We're not shocked by a car with fire damage on the side of the road, or an RV with a generator fire. Consumers understand that when engines or generators are worn, damaged or incorrectly designed, energy can escape in dangerous ways.

So how can our society get over the confusion of advanced energy technology and embrace new possibilities? It requires education, patience, and experience.

What's in a Name?

Lithium Ion is a cool sounding name, but it does a terrible job defining the product. Traditionally batteries are named for their chemistry. For example, lead acid batteries start our cars, and zinc batteries power our flashlights. Nickel cadmium batteries power our tools. But when the first lithium ion chemistry came to market in the 1990's, the makers decided to name it after the unique physics the battery operated on rather than the traditional chemical nomenclatures of the past. **In fact, there are over seven different basic chemistry types of lithium batteries on the market today and all of them are different in performance, capabilities, stability and many other properties.**

So the word *lithium ion* is similar to using the word *fuel* to describe gasoline, diesel, propane or any other gas or liquid fuel. It defines a category of energy chemistries. Simplifying the names to "lithium ion" creates a significant challenge when consumers try to make an informed decision in this new world of products.

Figure one below provides a list of the most common lithium ion chemistries and their applications.

Chemistry	Where the chemistries are generally used
LiFePo "Lithium Iron Phosphate	
NMC "Nickel Manganese Cobalt"	
NCA "Nickel Cobalt Aluminum"	
LTO "Lithium titanium Oxide	
LMO "Lithium Manganese Oxide	
LCO "Lithium Cobalt Oxide	
NCO "Lithium Nickel Cobalt Oxide"	

Figure 1: Common types of available lithium ion chemistries.

From figure one you can see that each of the lithium ion chemistries is suited for different applications, just like how different oil-based fuels are suited for different applications. We all know that gasoline doesn't work well in our gas grills. So how do we know what lithium works best for what application?

One of the most common chemistries is LiFePO4 or lithium iron phosphate. Most people refer to it simply as LFP. It's often marketed as the "safe lithium ion" and it is the most consumer-accessible lithium ion chemistry. It's often used in items like RC cars, toys like the hover boards, lead acid drop-in replacement batteries, and many more consumer electronics devices. LFP cells are so common that many of the DIY articles and videos that discuss working with Lithium Ion usually make the assumption that it's the only type of lithium. **If you are working with a lithium ion product that doesn't call out the type of chemistry, you should question the quality of the product.** You should also question the understanding of the manufacturer who made it. This would be like buying a new car but not knowing which type of fuel it takes.

Which Type is Safer?

We are all concerned with safety and we should be, but safety is relative to the concept of the product we have defined within our minds. Is gasoline safe? How do you define the safety of gasoline? Is diesel fuel safer than gasoline? Or how about natural gas, since natural gas is more difficult to ignite than other fuels, should we use it over gasoline?

On average gasoline is 30 times more energy dense than the best lithium ion chemistry on the market today, yet many of us sit on gallons of it every day on our way to work without concern. **Because chemistry does not define safety by itself, it is the overall system design that determines the safety and performance of any advance energy system.**

LFP chemistry is often marketed as a safer chemistry because if you take an LFP battery cell and compare it to another chemistry by puncturing them with a nail, the LFP cell will have less excitement (meaning no visible flame and a little bit of smoke). However, it still produces a lot of heat, enough heat to catch other materials on fire. One of the largest recalls in American history was the battery fire failure on LFP-powered hoverboards. Products like the recalled hoverboards are designed poorly; it's the design of the overall system, not only the energy chemistry that determines product safety.

Energy Density

We've all experienced when that important phone call suddenly drops, or that moment you need to take a picture and the dreaded "low battery" appears. We live in a world limited by energy.

Energy density is the amount of usable energy that can fit in a fixed amount of space. The chart below provides a simple way to see which chemistries provide more energy in a smaller space or for less weight.

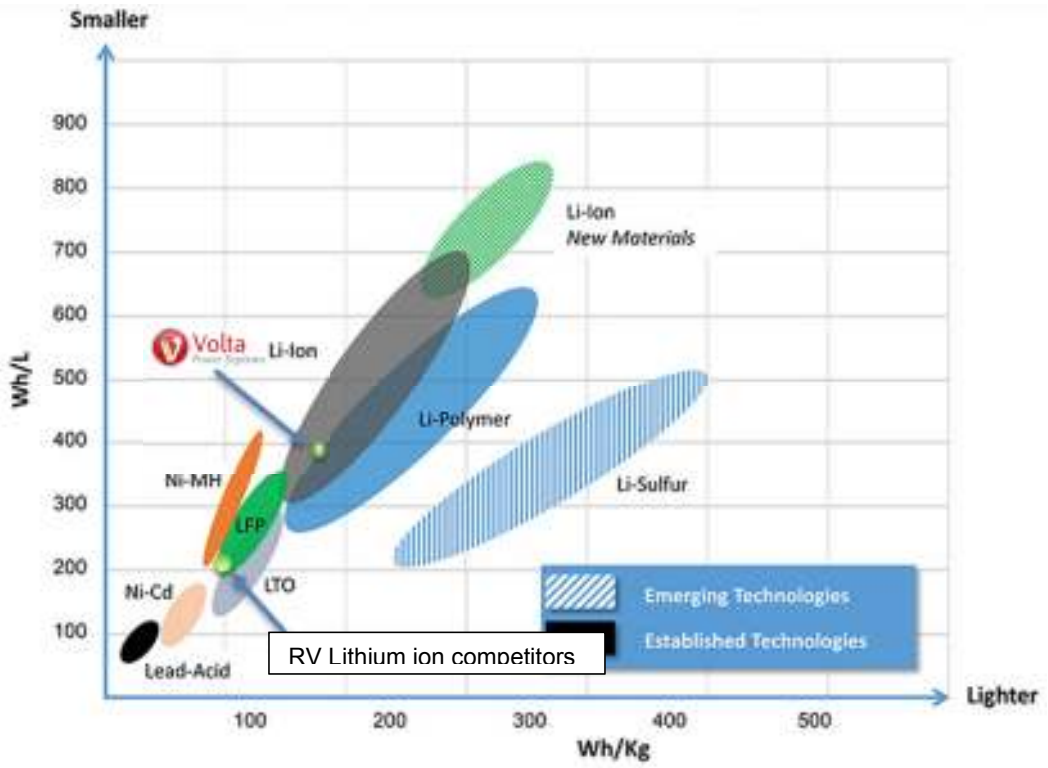

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Figure 1: Reference: New Tech Promises EV Charge time measured in Minutes; Jon Zeke: Aug. 26, 2011

Figure 2: Vertical axis more energy in a smaller space, Horizontal axis more energy for less weight

From the chart you can see why automakers and even consumer electronics companies are pursuing different chemistries. We all want our system to run longer, be lighter weight and cost less.

The best way to meet the consumer needs is to store more energy with less material in a smaller space. NMC (Nickel Manganese Cobalt) chemistry is generally two to three times more energy dense than LFP technology and simpler to monitor and control. **NMC is the dominate chemistry in the automotive industry. In fact, there are no mainstream domestic automakers using LFP chemistries in their automobiles for powertrain.**

Automotive Based Technology vs. Consumer Based

The word “engine” can mean a lot of things. A lawn mower engine is a lot different than a car engine and the engine in a diesel truck is dramatically different than a car but they are all engines. The same variation exists in the new field of Advanced Energy Storage “AES” systems.

When AES was first developed for mobile consumer devices like laptops, their design requirements were to provide the longest runtimes for the lightest and smallest possible form factors for a design life of around three years. The industry grew creating a huge manufacturing base that mostly produced a common size called 18650, which is like a big AA battery. The nomenclature stands for 18 mm diameter, 650 mm long. Millions of these cells are produced in the world each day, and until recently it was the best cost and only solution.

When Tesla came to market with the Model S, they used Panasonic 18650 cells produced in Nickel Cobalt Aluminum (NCA) and Nickel Manganese Colbalt (NMC) variants. Some 7,104 cells make up a Tesla 85 kWh battery pack. The advantage was the machines and supply chain existed to produce the NCA and NMC cells, and for a small startup company that was the best option. The problem with managing 7,104 cells with two connections each, is that over 14,000 discrete connections have to work together to be successful and there are many variables to manage at each connection.

The major automotive companies lagged behind bringing EV and PHEV technology to market because they had more to lose if they got it wrong. Decades of lessons learned on how to properly design a car and bring it to market with as few issues as possible deterred major automakers from bringing the small cell formats to market. So they chose to develop entirely new technology, equipment, manufacturing methods and integration technology, now referred to as large format cells.

Automotive lithium ion technology was designed to replace engines, so it had to work and survive the same conditions as car engines and last the same amount of time. Most automotive companies use a performance requirement to match the standard life expectancy of an engine. That's close to a minimum of 2,000 charge cycles, over 10 years of use, with 80% of their original capacity remaining at the end of that time.

Consumers receive mixed messages about the life of lithium ion technology. Often manufacturers say data like an individual cell may last 3,000 cycles or some as high as 6,000 cycles. With the original Tesla Model S, some battery packs have thousands of cells in the AES system. Each of these have to work together and can only function as good as the worst cell in the pack.

What is important is the life expectancy of the entire system and which design solutions ensure the cells and controls work together. To cover all of the variables that impact life performance of an AES system would far exceed the patience of the average reader, but a few of the most important variables that impact life are

· **Temperature**: High temperature operation and especially low temperature operation can impact life.
· **Current rate**: Increased energy pulled from the pack proportional to its rated size reduces life.
· **Material & manufacturing quality**: The quality of the product is only as good as the quality of materials and manufacturing you put into it.

· **System design**: How the systems are constrained and the ability of systems to control variables like vibration will impact life.
· **Battery management system control**: The BMS should prevent the battery from getting into any situation that could cause a safety issue or reduce its life.
· **Balancing capability**: How effective can the BMS keep cells at the same voltage compared to others in the pack?

A quality AES solution should address all of the above variables and more if they are to truly survive 10+ years of use.

Cost

The market is doing an excellent job finding ways to improve and reduce costs; much of the cost reduction is due to the acceptance that the consumer will invest in this new technology.

For the traditional user of lead acid technology the initial differences in cost might be difficult to understand.

Today you purchase a “black box” (a single battery) and it cost x amount of dollars. You likely associate the look and weight of the box to the value. However what you are really purchasing is length of time it can power a particular device. That’s right, the time honored revelation that **time is money**.

The industry even measures cost and price by looking at dollars per kWh. A kWh stands for the following. k = 1,000 W = Watts and h = hours. For example think of a 100w light bulb, you might think the 100W standards for how much light it can put out and most people do, but it really stands for how much energy it consumes.

So if you leave a 100 W light bulb on for an hour you would have consumed 100Whs of energy. Leaving the bulb on for 10 hours you would have consumed 1kWh of energy. An electrical Watt is a product of Volts x Amps.

Traditionally the battery world has sold product in terms of Amp hours. They did this because for the last 90 years batteries have been sold as 12V products. The voltage was always the same and it was easier to explain the difference in size of a battery in Amp hours.

In the AES world, Amp hours are not very useful to a consumer because everything they want to power is rated in Watts. The next time you look at your device tag you will notice there is a Wattage rating and then the type of voltage required.

Take a microwave. It might be rated at 1500 W at 120 Volt AC, or your TV might say 200 W. By adding up the consumption rating of your devices you can figure out how much energy you

need per hour to run everything. The more stuff you want to run and for more time drives the cost.

Here is an example:

Assume you want to run the following overnight in a motorhome:
· Air conditioner = 1200 Watts
· Fridge = 300 Watts
· Lights = 100 Watts
· General housekeeping loads 200 Watts
Total Power= 1800 Watts
To run 8 hours you would need (1800 W x 8 hours) = 14.4 kWh (14,000 Wh)

If you did that in a traditional 100 Ah (Amp hour) group 31 battery and followed the manufacturer's 50% depth of discharge requirement you would need
100Ah * 12V * 50% = 600Wh useable per battery.
Now divide 14,400 / 600 = 24 group 31 lead acid batteries to have similar amount of run time excluding efficiency losses.

Could you imagine purchasing 24 batteries for your RV, or boat? That would be approximately 1700 lbs of batteries. Could your vehicle support them? And what about the maintenance, let alone replacing them every two to three years? Over the lifetime expectancy of an automotive quality AES system, a lead acid equivalent would have consumed at least 72 batteries.

With a high quality system you are buying that amount of energy and life upfront along with the weight reductions, elimination of maintenance, and smell of traditional lead batteries.

Why is Volta Unique?

Volta's technology is specialized to work just below the touch-safe threshold of 60 Volts. By bumping the voltage up, we can provide over four times the available power for the same current. This allows us to produce incredible amounts of power out of very small devices.
For example, our alternators can produce up to 10,000 watts each, which is over four times the power of a standard 12V alternator of the same size.

This immense amount of energy can completely eliminate the need for the traditional onboard generators on most RVs, and in most cases provides more available energy than was ever possible. Finally, with Volta there is a solution that can truly make a mobile living space feel like home, because you can take your energy with you.

Volta is providing fully developed AES systems that are based on automotive, large format, NMC technology. This means up to three times the energy in the same space and weight as

LFP. Our background comes from the automotive hybrid industries, with world class leadership and development in both engineering design and manufacturing. We have taken those expensive lessons learned and integrated them into our technology.

Volta is not just about energy storage. We also provide power generation through our line of specialty alternators, as well as distribution with specially developed inverters and converters to provide the type of energy you need.

Volta provides the safest, most powerful, highest energy density, and long lasting complete solutions available for recreational markets.