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Runtime and capacity dominate thinking in a battery market that's still learning chemistry

By John Costa, Nexergy Inc.

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Scan the horizon of the battery technology market today. You'll see prominent technological landmarks familiar to everyone from the medical device designer to the commercial-off-the-shelf customer. Battery performance, as it relates to runtime and capacity, guides all of our journeys in search of market advantage. Such issues as weight, safety and cost—though obviously standard factors in design and manufacture—remain in a secondary position.

Numerous battery chemistries can be found on that horizon as well, from conventional lithium-ion to lithium-iron-phosphate to high-rate lithium-polymer. For a significant number of people in the industry, those many chemistries have created a sense of disorientation. *Which chemistry will serve my product best? Which will help me gain market leadership?* In a recent survey conducted by Nexergy, Inc., about a third of the design engineers and marketers interviewed were unable to identify their choice for their next portable power solution.

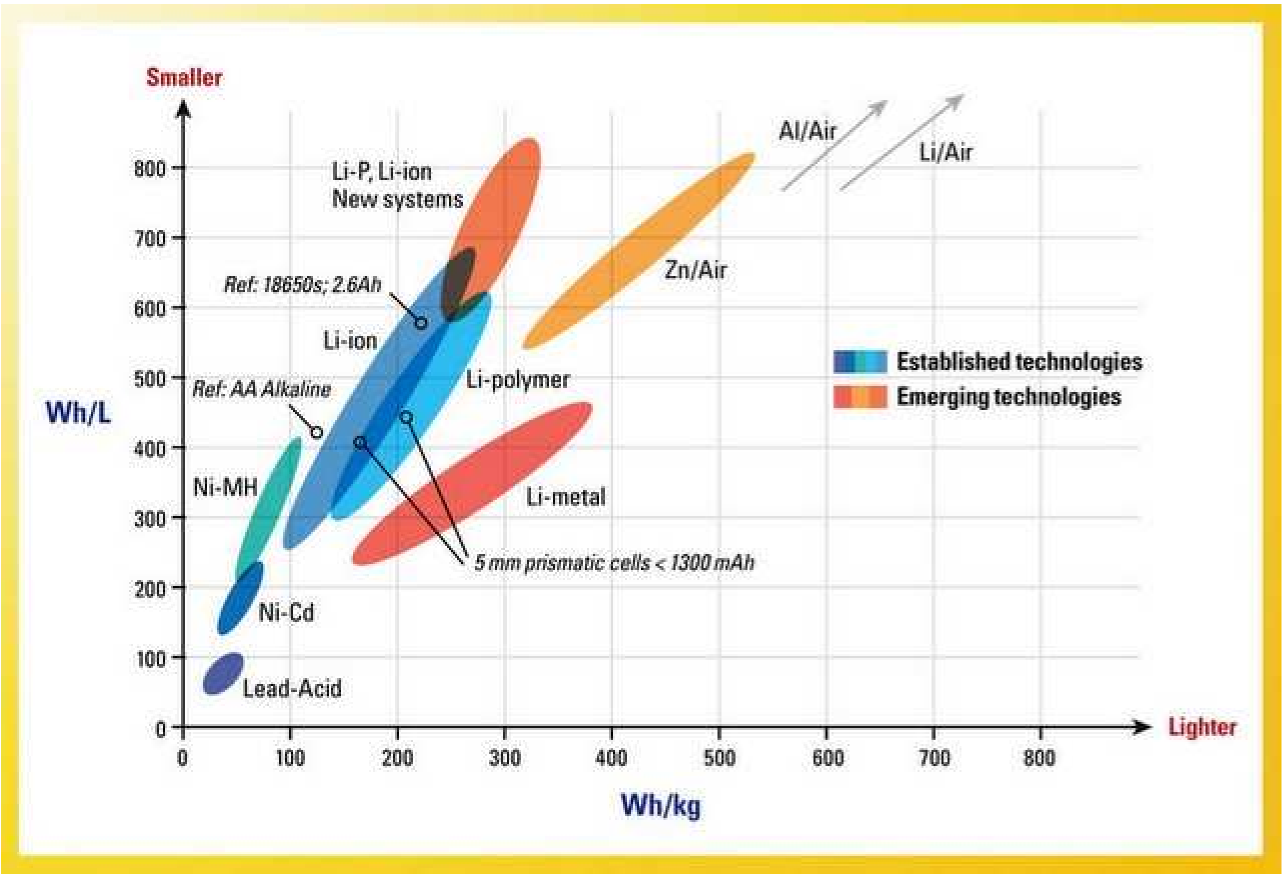
A desire for optimal battery performance and a knowledge gap regarding chemistries exist side by side in a market in which the majority of engineers consider battery pack performance as a key competitive advantage for products. Greater market education is an obvious long-term solution. Possibly less obvious is the design engineers' understanding that partnering with seasoned experts can help ensure competitive advantage today and in the future.

When the customer "walks through the door," the typical discussion begins with the topics of runtime, cycle life, and power. Engineers and designers are indeed confident that the better battery pack can create a competitive advantage for their products—but they may not know how to create that pack. For those engineers and designers, application-specific information becomes critical. Many questions need to be answered, including:

- How long must the device run between full charges?
- How much space and weight can be allocated to the power source?
- What is the load consumption of the device during operation or standby if typical applications include long periods of inactivity between uses?
- What are the minimum and maximum values for supply voltage?
- What is the pack output needed to meet the product's peak load or continuous current requirements?

- What is the acceptable battery life in the typical usage scenario?

With applications requiring a smart battery, optimal performance will also depend on the selection of the most appropriate gas-gauging technology and protection circuitry as well as the designing of the correct charge circuit, regardless of whether it is internal or external to the pack. Feedback from our study confirmed that the industry is coming to appreciate these aspects of the design challenge. Ensuring that the gas gauge is accurate, or that the charge or discharge cycles don't terminate prematurely or that the pack is not abusively charged or over-discharged affects realized capacity, safety and cycle life.



Safety is a significant part of a design matrix. When respondents were asked about which performance improvements are "most critical" to adding value to the end product, design engineers ranked safety as number two out of a seven-choice ranking in which one is most critical and seven least. Marketers listed safety right in the middle of this ranking. Safety is on customers' minds more than ever. That's always a big question during our customer meetings. Customers want to know if a change in battery chemistry will affect safety.

As far as cost is concerned, our survey delivered an unexpected result. Cost appeared low on the priority list for design engineers, and nearly at the bottom among our marketing contacts. Cost can never be totally discounted, but battery performance is clearly seen by our customers as the core competitive advantage.

The underpinnings of the core competitive advantage lie in the battery chemistries themselves. That fact again underscores the need for continuing education about those chemistries. Take lithium-ion iron-phosphate ($LiFePO_4$) as one example. More than 40 percent of the design engineers and marketers were unaware of the features tradeoffs with this chemistry. They didn't know that $LiFePO_4$ offers excellent cycle life, high rate capability and a high level of safety. At the same time, this chemistry has lower energy density compared with conventional lithium-ion.

Battery	Voltage	Energy Density	Pros	Cons
Rechargeable				
Sealed Lead Acid	1.5V	60Wh/kg 100Wh/L	Best suited to stationary or wheeled applications, SLA batteries are easy to maintain, have low self-discharge rates and are less expensive than other rechargeable batteries.	Low energy density makes SLA batteries bulky and heavy. They must be stored in a charged state.
Nickel Cadmium	1.2V	90Wh/kg 210Wh/L	Robust and relatively inexpensive, NiCD batteries are typically used for applications in which long life, high power and extended temperature range are important.	The potential for voltage depression ("memory effect") and the fact that NiCD batteries contain toxic cadmium, which requires recycling, have made them less popular.
Nickel Metal Hydride	1.2V	125Wh/kg 400Wh/L	NiMH batteries can have capacities as much as 90 percent higher than equivalent size NiCD cells. They have less "memory effect" and are environmentally safe and lighter in weight.	NiMH batteries have a slightly lower cycle life and require a more sophisticated charge control. In terms of equivalent cell sizes, the cost for NiMH is more than that for NiCD, but the cost per Wh is the same or less.
Lithium Ion	3.6V	240Wh/kg 550Wh/L	The high energy density Li-ion chemistry reduces the cell's weight by half and the volume by 20 to 50 percent. The self-discharge rate is less than half that of nickel-based chemistries, and there is no "memory effect."	Rechargeable Li-ion cells are more expensive than both NiCD and NiMH, and they require protection circuitry to keep voltage and current within safe levels. All lithium-based chemistries are subject to shipping regulations.
Lithium Ion Polymer	3.6V	260Wh/kg 540Wh/L	Li-Polymer batteries have greater energy density in terms of weight than Li-ion. There is more flexibility in cell sizes and shape with Li-Polymer and a wider margin of safety, with superior stability in over-voltage and high temperature conditions.	Li-Polymer batteries command a slight premium price. The cells require protection circuitry. They are subject to shipping regulations.
Lithium Ion Iron Phosphate	3.3V	108Wh/kg 220Wh/L	Excellent cycle life, high rate capability, and best in class safety	Low energy density compared to conventional Li-ion chemistries
Primary (Non-Rechargeable)				
Alkaline	1.5V	125Wh/kg 400Wh/L	Long shelf life, low cost and reasonable drain rate make them attractive for commonplace applications.	Poor low temperature performance, high impedance
Lithium Iron Disulfide	1.5V	310Wh/kg 560Wh/L	Patented lithium technology from Energizer used in industrial applications such as asset tracking due to its excellent rate capability and low temperature discharge capability (down to −40°C). Shelf life to 15 years.	Voltage is half of other lithium primary chemistries, thus typically requiring more cells in series to get desired voltage. Subject to shipping regulations.
Lithium Manganese Dioxide	2.9V	240Wh/kg 500Wh/L	These batteries offer high energy density, extremely long life, a wide operating temperature and excellent durability. They offer much higher energy density than alkaline.	Like their rechargeable counterparts, they are subject to shipping regulations.
Lithium Sulfur Dioxide	2.8V	265Wh/kg 400Wh/L	The batteries share lithium primary advantages. They also have good high rate capabilities and perform well at low temperatures.	Like their rechargeable counterparts, they are subject to shipping regulations.
Lithium Thionyl Chloride	3.6V	520Wh/kg 1050Wh/L	The batteries share lithium primary advantages. LiSOCl2 cells have the highest energy density of all Lithium types. Service life is typically 15 to 20 years.	Like their rechargeable counterparts, they are subject to shipping regulations.

Download Chemistry Comparison Chart

The fact is that there are so many different variants of lithium-ion cells, not every one fits every application. Some are better suited to high temperature; some to low temperature; some are ideal for supporting higher discharge rates. The key element is to understand all the different cell chemistries available and to select the right one that delivers the longest runtime and overall performance while taking into account the application's other requirements such as size, cost and weight.

Beyond the issue of battery chemistry, we learned that there is confusion with regard to the shipping of lithium batteries, which can become a key factor in weighing pros and cons of battery chemistry choices. Nearly half of the design engineers Nexergy had contacted for our recent survey admitted that they were "not very aware" of the new DOT shipping regulations.

For the manufacturers of battery packs and chargers, the challenge of serving today's market appropriately is clear. We must step into the dual role of educator and design-manufacturing partner. The companies best prepared to take on this role are companies with expertise across chemistries, from sealed lead-acid to lithium-ion to new and emerging chemistries such as lithium-ion iron-phosphate.

In summary, proper cell selection and battery electronics can indeed create the competitive advantage for a manufacturer that seeks a portable power solution. An alliance with an expert in portable power design, integration, and manufacturing can ensure it.

About the author

John Costa joined Electritek AVT in June of 1999 as a Vice President, Battery Charger Group. He was responsible for their battery charger business development until 2002, when he was promoted to the position of Chief Operating Officer. With the merger of Electritek AVT and Nexergy (Columbus, Ohio) this year, John has assumed the position of Executive Vice President of the new company and heads up their New Business Development Center responsible for sales, marketing, and product development.