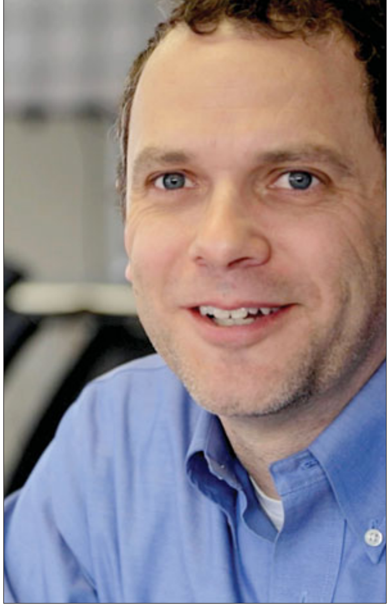
Manufacturing energy: Jay Whitacre zeroes in on what technologies address the market

Interviewed by **Steve Yalisove** and **Judy Meiksin**



In just five years, materials researcher Jay Whitacre—the Founder and Chief Technology Officer of Aquion Energy—raised $7.5M, then $30M, then another $35M that was quickly increased to $55M for his battery company, which is located in the Greater Pittsburgh Area. All the while, Whitacre also kept a professorship at Carnegie Mellon University. When asked how his approach to sodium-ion batteries differs from that of other beyond-lithium technologies, Whitacre said that rather than address energy density, "the focus that we have is about cost, performance, and durability." Furthermore, to reach commercialization, a proper environment must be arranged from the outset.

***MRS BULLETIN*: What were the challenges of launching a start-up, particularly in light of being an assistant professor when the venture started?**
JAY WHITACRE: CMU embraced the idea from the beginning. I've always made sure that the research going on in the university lab is focused on answering key fundamental questions that produce publishable results. I had 18 months of this "academic incubation" before the company was spun out, at which point I took several semesters of leave without pay so I could help the company along. During this time, I was an assistant professor and thought that these activities might slow my progress toward tenure. However, I have found that, at least at CMU, there is so much interest in innovation and entrepreneurship that my experiences have allowed me to be a more effective and productive professor in some ways.

What attracted you to aqueous sodium-based batteries?
"Lithium-ion battery materials" was a very populated field in 2007 when this project started, and I saw cost and practical reasons, as well as professional reasons, to move into the aqueous/sodium systems. Most Li-ion researchers spend their time in glove boxes and dry rooms to fight moisture, so it's almost ingrained that you would never put these material in a water-based electrolyte: It won't work. Right? But in fact many insertion materials are fully stable in water if they have the right redox potentials.

Additionally, as an ion conductor, water is at least an order of magnitude better than the organic solvent-based electrolytes in lithium-ion batteries, and many orders of magnitude better than solid-state systems (which I worked on for years at Jet Propulsion Laboratory before my move to CMU).

At CMU, one of the first things I did was assess what my skill sets were and what I thought the world needed.

Low-cost energy storage for stationary applications for multiple-hour storage existed, but not to the extent needed. There was lead acid, sodium sulfur, and a couple of other technologies, but they were expensive, or full of toxic materials, or hazardous. I thought that if I could do this with a neutral pH aqueous sodium-based electrolyte, find materials that had intercalation/deintercalation behavior, and if those materials were cheap, abundant, and manufacturable, then I'd have a potential solution. The transition to aqueous would allow me to have thick electrodes, fast ion conduction, and low-cost manufacturing.

The next obvious question is what's the cheapest cation? That is, per mole? It's sodium. In that timeframe, 2007 to 2008, almost no one had looked at sodium-ion functional materials in a water-based system.

How does your approach differ from that of other beyond-Li technologies?
Researchers who work with more standard batteries for computers, cell phones, or cars are typically focused on high energy density. However, the more energy you ask any material to give and take per unit mass, the more apt it is to be unstable over thousands or even hundreds of cycles. The paradigm change I examined was setting aside the need for high energy density and focusing on long, stable cycle life. The materials we use are also very common and have been studied for years in other forms. For example, manganese oxide is not exciting; there are numerous papers on it. But learning how to use it in just the right environment is a big deal. So the focus is more pragmatic and less headline-grabbing, I think, than most "beyond-lithium" battery research.

In raising funds, what is your magical touch?
There's no magical touch; it's about having compelling data and talking to the right people at the right time. In 2008, the venture community had the sense that the next revolution was going to be energy technologies. Kleiner Perkins Caufield & Byers (KPCB) was the first firm to invest in me. KPCB

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The battery stack serves as the fundamental building block of Jay Whitacre's aqueous hybrid ion systems.

Partner Bill Joy, the co-founder of Sun Microsystems, and another partner by the name of David Wells came to CMU every other month and would help shepherd me through the thought process of technology development. The investment came early in the development process because KPCB and a couple other folks had on their map of technologies plans to fund low-cost stationary energy storage that was very robust and could be manufactured easily. These firms seeded a lot of ideas, and I was one of those seeds. Some of them, through natural attrition, didn't make it past the early incubation phase—and we almost didn't make it on two different occasions! But we went in the lab, failed fast, figured out what would work instead, and pivoted to a usable solution. Subsequent fundraising rounds were all about first telling a compelling technical story with solid data, and then showing a compelling marketplace story.

What tasks remain before you compete commercially?

The folks who made our battery assembly line have just finished tuning up and replacing a couple of robotic arms; and now we're going to be doing our production validation run: we build multiple thousands of batteries and do full QA assessment of them. Then sometime in June, we will be into high volume production. In the meantime, we're still selling and shipping batteries to partners and early customers.

What materials challenges should society be addressing?

I'll re-scope this question and talk about the "materials for energy technologies" category. I think a lot of researchers vastly underestimate the scale of the problem and how important manufacturability is.

In general, the requirements such as extremely high purities, low defect densities, and the need for energy-intensive processing to make a device is not scalable. For our company to make batteries at a relevant scale next year, we're processing at least a metric ton of anode and a metric ton of active materials per hour, so when you think about what is needed to impact the world, it's daunting, and most research results don't address how to get to that size/scale. The question is, "How do we redirect this line of research so that it is inherently more practical?"

How can public policy help?

Another reality about materials for energy technologies is the infrastructure needed to scale them. To manufacture the device in the US, you're going to have to build a factory. The factory is going to cost $50–$200 million. You've got to be ready to front that money and watch some of them fail. Solyndra, A123 Systems, and Fisker took government loans and have since struggled, but Tesla has been a real success story. One of the criticisms of the [US] government is there's this perception of picking winners and also a perception of losing public money. We have to educate the public in that even some of these failures weren't—the money *did* go into the local economy, people *did* get jobs. The people who worked at Solyndra then went on to proliferate four or five other companies that are doing well now—that is money not wasted. Understanding how to represent the fact that failure is part of the process is important. The quieter way to do this is to figure out how to create good incentive structures for using technologies. California passed a series of incentive measures for energy storage to go along with their solar mandates; they're very bold. Countries like Germany have been very successful in encouraging new energy technologies.

The "failure room" at Aquion Energy, where pieces of equipment used to attempt new process approaches (most of which were set aside promptly) are stored.

What's next?

Our current core product, which we call a "battery stack" is about 1.5–2 kWh of storage, very robust, and it will cycle for a long time. We can get much more energy in that same package; however, we have to optimize our production and electrode recipes. So what's next is tuning in and costing down our current design, then using this platform as we incorporate our next generation of materials. □

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