POWER PLAY

With their **LIQUID METAL BATTERY TECHNOLOGY**, Don Sadoway and David Bradwell tackled the challenge of delivering low-cost, large-scale electricity storage to supplement an overtaxed grid.

"Only work on big problems."

That, says David Bradwell, is the most important lesson he has learned from collaborating with Professor Donald Sadoway. "If you want to have an impact, focus on really big issues. That's the highest value use of your time."

True to that philosophy, Bradwell and Sadoway in 2005 took on a major challenge facing the energy industry: how to provide large-scale, low-cost electricity storage to enhance the reliability and security of the power grid. Initially funded by the Deshpande Center and now in commercial development, their proposed solution — liquid metal battery (LMB) technology — shows great promise for several applications including:

- Reducing exposure to blackouts and brownouts
- Smoothing out fluctuations in the power generated by intermittent renewables (wind and solar)
- Positioning extra capacity downstream from congestion points in the distribution network.

PUMPED HYDRO: AN UPHILL CLIMB

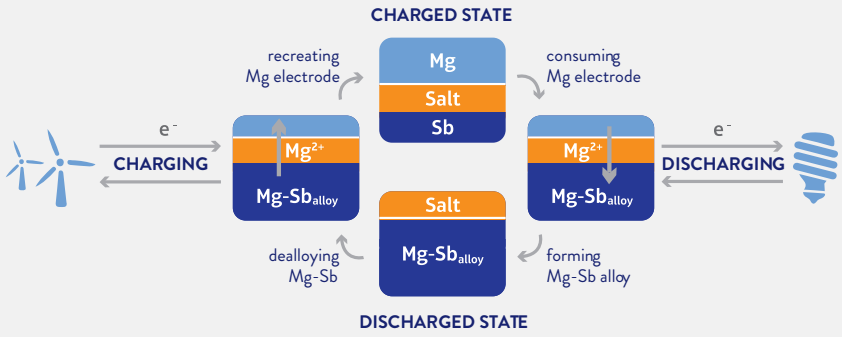
Recognizing that market economics greatly favor the traditional pumped-hydro method of power storage — where water is pumped uphill, stored at elevation and released to drive turbines — Sadoway and Bradwell decided that low cost and flexible siting must be core principles of their battery design. Sadoway says, "We agreed we would invent to the price point of the electricity market. This meant the battery would have to be made from low-cost, earth-abundant materials and be constructed using low-cost, scalable manufacturing techniques. If you want to make something dirt cheap, make it out of dirt."

One source of inspiration was Sadoway's insight about aluminum smelting, which uses large quantities of electricity to produce molten aluminum at low cost and huge tonnage. The challenge would be to discover reversible chemical reactions involving liquid metals to endow a battery with massive capacity. And, by the way, the battery would also have to handle high-current charging and discharging while offering long service lifetime, easy deployment and simple maintenance.

As Sadoway's first graduate student on the project, Bradwell's mission was to work out the LMB concept on paper and then make it work in the lab.

KEY INNOVATORS

- DONALD SADOWAY, John F. Elliott Professor of Materials Chemistry at MIT, co-founder of Ambri
- DAVID BRADWELL, Ph.D., co-founder and Chief Technology Officer of Ambri
- GERBRAND CEDER, Richard P. Simmons Professor of Materials Science and Engineering at MIT



THREE LIQUID LAYERS

In the lab, Bradwell worked out the initial cell chemistry based on magnesium (Mg) and antimony (Sb). Heated to a molten state, the metals segregate into three layers: a negative Sb electrode, a molten salt electrolyte, and a positive Mg electrode. Applying current in one direction charges the battery; allowing current to flow in the other direction generates electricity and discharges the battery. Ambri has since transitioned to a higher-voltage, lower-cost chemistry.

FROM GRAD STUDENT TO CTO IN FIVE YEARS

David Bradwell credits support from the Deshpande Center with transforming him from a struggling graduate student working on a promising idea to the CTO of a highly touted startup company in just five years. In the spring of 2006, he had already spent months exploring the LMB concept under Sadoway's guidance. But now, nearing the end of his Master's program, he was facing unemployment and worried he would have to take a funded position elsewhere.

OFF THE COUCH AND INTO THE LAB

Hoping to keep the project alive, he and Sadoway applied for a grant from the Deshpande Center. Although the LMB concept was completely untested, their proposal was quickly approved. The grant gave Bradwell "visiting scientist" status and a steady income. "More importantly," he says, "it got me off my living room couch, where I had done much of the conceptual work, and into the lab so I could start running experiments." It also put him in regular contact with other researchers who had relevant experience in electrochemistry and high-temperature systems.

OUT OF THE LAB AND INTO THE MARKET

The renewal of the Deshpande grant followed, enabling Bradwell to start his Ph.D. By 2008, he had created a working LMB prototype the size of a shot glass. This early success attracted financial support from Lightspeed Venture Partners, the Chesonis Family Foundation, and the Massachusetts Clean Energy Center. In turn, that was followed by major funding from the Department of Energy's ARPA-E[1] program and the French energy company Total S.A.

> *"If you want to make something dirt cheap, make it out of dirt."*
>
> DON SADOWAY
> on using earth-abundant materials to create a low-cost solution

In 2010, Sadoway and Bradwell co-founded Liquid Metal Battery Corporation (now Ambri), an event Bradwell traces directly to the center's support. "Without that initial funding, we all would have moved on to other things," he says, noting that the company is on track to ship its first commercial product in 2014.

[1] Advanced Research Projects Agency for Energy