

# Storage

## HOW TO CATCH THE WIND

A storage-battery startup could pave the way to wider use of wind and solar power.

BY MIKE VARGO

On November 8 of last year a milestone was reached. It happened in Spain, when strong winds swept the coastline, the mountains and the plains of La Mancha. Wind turbines across the country spun furiously, and for a brief time — about an hour and a half — a renewable energy source was

meeting more than 50 percent of an entire country's demand for electricity.

Nice, but hold the victory cigars: that was between 4:30 AM and 6 AM, not exactly a high-demand period. And one problem: later on, when demand rose, the winds died down. "Wind and solar power are intermittent; they're spiky. This limits how much we can use them, because electric grids need predictable power," says Jay Whitacre.

Whitacre, a professor with a joint appointment in Materials Science & Engineering and Engineering and Public Policy has a solution. A race is now on to develop low-cost, large-scale storage batteries. Any country (including ours) could then have many more wind and solar farms, generating as much power as possible whenever they can, and storing the surplus for use as needed. Whitacre and his Carnegie Mellon group believe they've got a storage technology that can be a winner.

It's called an aqueous electrolyte sodium ion battery, not to be confused with the sodium-sulfur batteries already on the market. The latter works well but as Whitacre notes, "the cost point for these is high and you have to keep them hot," since they use molten materials inside specially sealed chambers. Whitacre's sodium ion batteries are projected to be much cheaper, need no special handling and are themselves environmentally benign. Says Whitacre, "You could eat the battery."

Recent working prototypes are small disc-shaped cells about the size of ones you'd put in a wristwatch. The cells will be made larger and stacked to form true "batteries." The stacks would in turn be bundled into mega-batteries, Whitacre says: "Fill a cargo container with them, and have two big bus bars coming out as your terminals." Finally, a large user could simply throw up a prefab building and fill it with containers.

A spinoff company, Aquion Energy, has been started to further develop and manufacture the sodium ion batteries. Aquion has substantial venture funding plus a \$5 million grant from the U.S. Department of Energy's Smart Grids Demo Program (in partnership with Carnegie Mellon). Located in Pittsburgh's Lawrenceville industrial district, with room to expand, the firm employs about a dozen people currently and expects to be manufacturing batteries by early to mid-2011. All this has grown quickly, out of a research project that didn't exist three years ago.



Jay Whitacre

### Moving from Mars to Molasses

Jay Whitacre came to the faculty in 2007 from NASA's Jet Propulsion Laboratory in California. There he studied materials for batteries for interplanetary space, which was fun, he says, "but I wanted my work to have wider impact." At Carnegie Mellon he saw a chance to get an early jump into an emerging high-need area: "Lots of people were working on batteries for electric vehicles, trying to stuff a lot of power into a small package. But there was much less research going on in low-cost stationary storage for the power grid — and there's a fantastic group of people here who do electrical industry work, like Granger Morgan and Jay Apt in EPP (Engineering and Public Policy)."

Talks with Morgan, Apt and industry contacts made it clear that the key factor is cost. Existing storage batteries like the molten sodium-sulfur units have been far too pricey for most firms venturing into wind and solar power. Instead they use natural gas turbines as standbys. When the wind isn't blowing or the sun doesn't shine, they fire up the turbines to keep feeding power to the grid. That is not an all-renewable system but it's the best available, used widely in Spain (a leader in wind power) and elsewhere.

So Whitacre's group began by setting a cost target. To compete with the gas turbines, they'd need a cheap battery capable of storing and delivering electricity over a





# Technology

ten-year lifespan. No technology being tried at the time could come close to the requirements, Whitacre says, “so the question became, ‘What can we make this thing with?’”

The battery had to be rock-simple and use cheap, everyday materials. At times, Whitacre’s lab in Wean Hall resembled a cooking class. Incoming materials included, for instance, sacks of sugar. “The anode is activated carbon,” Whitacre explains, “and big carbon producers will charge you fifty to a hundred dollars per kilogram. We need to be under five or ten. So we make our own carbons” — which can be done by processing various carbohydrate materials streams, all of which were experimented with.

As for the cathode, Whitacre points to a small plate of dark-brown powder on his desk. “Manganese dioxide,” he says. “One of the cheapest purified metal oxides you can buy. Mix it with sodium bicarbonate (baking soda) and heat it up. You get sodium manganese dioxide.”

The electrolyte is just salt water, with sodium sulfate as the salt because sodium chloride, or table salt, would emit chlorine gas when the battery operates. Says Whitacre, “Most batteries use organic electrolytes. By using an aqueous electrolyte, we sacrifice energy density,” i.e., the ability to pack more punch into every cubic millimeter. But for stationary storage he figured that space isn’t at a premium and it’s better to be “much cheaper, with no toxic or flammable materials.”

## Hurdles and Fences

Cooking up the battery wasn’t nearly as easy as it may sound. Among a host of design problems, there has been much tinkering to make the surface characteristics of the activated carbon just right. On the cathode side, getting the optimum mix of sodium ions in a manganese dioxide crystal structure was tricky, too.

Even the name of the startup company had to be changed. It was originally 44 Tech, after the first cathode formula used,  $\text{Na}_{.44}\text{MnO}_2$ . “Then we learned that four is an unlucky number in China,” Whitacre laughs. “And ‘44’ would be double-death, like calling your company ‘13 plus 666.’” Hence, Aquion Energy.

Whitacre is Acting Chief Technology/Science Officer at Aquion. He’ll take an academic leave of absence in the 2010–11 school year as the firm ramps up toward production. The road ahead won’t be easy either. Competing technologies are emerging, though sodium ion has to be seen as a front-runner, especially since winning one of the hotly contested Energy Department grants. Also, big sales to utility companies won’t come right away. “Maybe we’ll start by selling smaller units to residences and buildings that have solar panels,” Whitacre says, noting that “It will take a while to build a factory that can make the size of battery useful on the grid.”

Having a big new manufacturing firm in post-industrial Pittsburgh is quite a prospect. But wouldn’t other firms try to acquire the technology before that stage, and mightn’t it be tempting to just cash out? Anything could happen, but as for now, Whitacre says, “We’re swinging for the fences.”



## IT'S BEST TO BE ARMED FOR THE WORST

Silicon Valley campus blazes new ground in disaster management technology.

BY MIKE VARGO

boats riding the waves, he recalls. Luckily for Griss the 1989 Loma Prieta earthquake did its most severe damage farther north, in the Bay Area, killing 63.

In California and elsewhere, there's always the risk of an even worse event. And when Griss, a noted software expert, was named Director of Carnegie Mellon Silicon Valley last year, he began bringing the campus into the forefront of a critical research area: disaster management. The work involves helping people to respond better — saving lives, minimizing loss and disruption — when struck by natural disasters or other crises such as epidemics or terrorist attacks.

Hurricane Katrina and this year's earthquake in Haiti brought home the need. But the Haiti tragedy also pointed to opportunities, says Griss. Although the country was not well prepared and the toll was grim, he says, "the use of technology changed the response profile. It was more rapid than it was in Katrina, more powerful in some ways." Haitians on the ground amid the wreckage used their cell phones to text on-the-fly damage reports and requests for help. At ad hoc "CrisisCamp" locations in the U.S. and other countries, IT-savvy volunteers used new open-source software to sift and relay information: feeding situation maps and lists of needed supplies to relief teams, trying to track down missing family members and more.

To Griss, what's been done is just a glimpse of what's possible. "There are entire chains of possibilities for future work," he says, "and I don't think they've all been articulated, let alone explored and implemented." Under a new Carnegie Mellon program called DMI, the Disaster Management Initiative, the Silicon Valley campus is bidding to become a hub of this work.

### Here's What We Need ...

Steven Ray, a Distinguished Research Fellow at Silicon Valley, is on the phone with a tentative agenda he's sketched out for DMI. The call takes nearly two hours. This spring, the Silicon Valley campus had held a three-day workshop and CrisisCamp to invite input

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from potential partners such as fire and police departments, state agencies like CalEMA (the California equivalent of FEMA) and high-tech firms and groups. Ray had then boiled down the input to a list of 13 broad "areas where we can do some useful work," each a research agenda unto itself.

One priority item is developing a COP, or common operating picture, for all the parties that might have to respond to a disaster. "A lot has to do with just figuring out what's happening," says Ray. "Where are buildings collapsed with people in them? Which roads are blocked; who needs what and where are they? There can be all kinds of information coming in — satellite images, sensor alarms, field reports. You have to collect it all, fuse it into a model that makes sense, and communicate it to whoever needs it."

Ray calls this a huge "data interoperability problem," which he says "we're well suited to address at Silicon Valley, with our skills in fields like software and mobile systems." He notes that it's a problem with many complications.

For instance, "in Katrina, they'd get calls saying 'I'm at such-and-such address, pinned in, my grandmother is dying.' But with all the rubble, street addresses were often useless. Streets were

not even findable. You need geospatial coordinates," Ray says. Security is an issue,

too: "How do you trust information coming in? And who gets to know what? If water lines are broken in a quake, that's important news. But the utilities want to guard information about where the mains are and where the water goes. Somebody could dope the water very easily."

Also needed are systems for tracking and directing responders on the scene. One scary task is sending firefighters into a burning building. They may have trouble finding people who need to be rescued, or not know which parts of the building are about to give way; they can get lost and never get out. The ideal would be to have something like the magical Marauder's Map in the Harry Potter books: a multilevel floor plan of the building, with moving dots to indicate people, and with dangers shown.

In fact, such a system is in the works at the Valley campus. It's called the Open Floor Plan. Digital layouts of major buildings aren't hard to come by. Adding in data from smart-building sensors, plus mobile sensors carried or launched into interior spaces, would fill out the picture. Firefighters could then see what's up on wearable displays, or commanders outside could direct them to safety.



Martin Griss



Steven Ray



# management initiative



That is, unless communications are knocked out — a major fear. “In 9/11, police and fire responders couldn’t talk on their walkie-talkies,” notes Ray, and for any wide-area disaster “you have to assume you’ll lose cell phones or Internet, because networks are either broken or overloaded. You need backup systems with no single point of failure.” Two backup technologies being explored are radio-based Internet and E-MESH, a new emergency wireless system that Ray and others had a chance to test in action recently, when a fire miles away in San Francisco destroyed the fiber-optic Internet line to the campus.

California is an ideal place to develop and test new disaster systems, for a most ironic reason: public budgets are squeezed. Anything new has to be very affordable so that it can be widely used. Steven Ray says another key is not to develop “stuff you pull out of a box” only in a major catastrophe, but focus on technology that has everyday use as well. Radio-based Internet stations, for instance, might be “located at schools where teachers and students can use them for educational purposes, but quickly repurposed during an emergency.”

### A Bubbling Stew

The whole research initiative is being built from the ground up on partnering and collaboration. Open-source coders living in the Valley wrote the E-MESH software, now in beta. Local police are looking for technology to help enable “citizen response” to a disaster — so that people can not only call in reports and requests, but be organized to quickly help one another, with block captains and so forth — because professional responders and relief teams can’t be everywhere right away. Ushahidi, a global network of high-tech disaster-response volunteers that started in Africa, had delegates at the campus workshop this spring.

Moreover the Silicon Valley campus is at Moffett Field, on the grounds of the NASA Ames Research Center. NASA’s own Disaster Assistance and Rescue Team (DART) is based here, and hosts training programs for responders nationwide.

While many are working on disaster technologies, Carnegie Mellon brings a unifying element to the picture, says Martin Griss. “As a university, we can do big-picture research that doesn’t go directly to a one-product solution the way

a company might. With our faculty and Ph.D. students, we have smart people who are going to work really hard to solve tough problems in a novel way. And we’re neutral territory for joint work.”

Right now Griss is raising funds to grow the Disaster Management Initiative. And with so many new ideas being brought to bear in this field, he sees future applications going well beyond disaster management. “Crowd-sourcing, the power and ubiquity of mobile devices, servers in the cloud — they’re all coming together in a stew that can feed many human needs. It’s like when the telegraph first came in, linking and empowering people, except much more so. And we are in the middle of it.”



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