REPORT

The Challenge for Green Energy: How To Store Excess Electricity

For years, the stumbling block for making renewable energy practical and dependable has been how to store electricity for days when the sun isn't shining and the wind isn't blowing. But new technologies suggest this goal may finally be within reach.

BY JON R. LUOMA

“Why are we ignoring things we know? We know that the sun doesn’t always shine and that the wind doesn’t always blow.” So wrote former U.S. Energy Secretary James Schlesinger and Robert L. Hirsch last spring in the *Washington Post*, suggesting that because these key renewables produce power only intermittently, “solar and wind will probably only provide a modest percentage of future U.S. power.”

Never mind that Schlesinger failed to disclose that he sits on the board of directors of Peabody Energy, the world’s largest private-sector coal company — a business with much to lose if a solar- and wind-powered future arrives. But at least he and his co-author got it partly right. The benefits from wind and solar are mostly intermittent — so far. But the pair somehow missed the fact that a furious search for practical, affordable electricity storage to beat that intermittence problem is well underway.

For decades, “grid parity” has been the Holy Grail for alternative energy. The rap from critics was that technologies like wind and solar could not compete, dollar-for-dollar, with conventional electricity sources, such as coal and nuclear, without large government tax breaks or direct subsidies. But suddenly, with rapid technological advances and growing economies of manufacturing scale, wind power is now nearly at grid parity — meaning it costs roughly the same to generate electricity from wind as it does from coal. And the days when solar power attains grid parity may be only a half-decade away.

So with grid parity now looming, finding ways to store millions of watts of excess electricity for times when the wind doesn’t blow and the sun doesn’t shine is the new Holy Grail. And there are signs that this goal — the day when large-scale energy storage becomes practical and cost-effective — might be within reach, as well. Some technologies that can store sizeable amounts of intermittent power are already deployed. Others, including at least a few with great promise, lie somewhere over the technological horizon.

New storage approaches include improvements to existing lithium ion batteries and schemes to store energy as huge volumes of compressed air in vast geologic vaults. Another idea is to create a network of small, energy-dense batteries in tens of millions of homes. Under such a "distributed storage" scheme, utility computers could coordinate electricity flows over a "smart grid" that continually communicates with — and adjusts the flow of power to and from — local batteries. This would even include batteries in future plug-in hybrid or all-electric vehicles.

Large-scale electricity storage promises to be a game-changer, unshackling alternative energy.

And one 2008 breakthrough could even fulfill chemists' long-held dreams of producing a squeaky-clean and storable fuel by using excess electricity generated from renewable sources to cheaply produce hydrogen, which could then be used in fuel cells to power homes and cars.

In a world run mainly on fossil fuels, finding ways to store electricity was not a pressing concern: Power plants across a regional electrical grid could simply burn more fuel when demand was high. But large-scale electricity storage promises be an energy game-changer, unshackling alternative energy from the constraints of intermittence. It would mean that if a wind or solar farm were the cheapest and cleanest way to generate power, it wouldn't matter when the sun shone or the wind blew.

One storage approach seems obvious: to improve battery technologies. Picture efficient, enormous batteries that can store tens of millions of watt-hours of juice. Today, the vast majority of new rooftop solar photovoltaic panels are connected to the grid, using it as a giant battery, pushing excess power onto the grid when solar panels provide excess power. The building then draws power from the grid when the sun doesn't shine, with its meter spinning backward and forward with the ebb and flow of power. With relatively few solar roofs yet in play, utilities manage any ebb and flow by drawing down and ramping up generation at conventional power plants designed to

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balance fluctuating supply and demand.

A more robust world of solar and wind power might be better served by some sort of giant battery — or, more likely, many of them, widely distributed. The basic concept has been proven. Since 2003, the world's largest battery backup has been storing energy for an entire city: Fairbanks, Alaska. Isolated as it is, and not part of any regional electricity grid, the metropolitan area of about 100,000 residents needs an electricity backstop more than most: In its sub-zero winters, pipes can freeze solid in as little as two hours. Six years ago, the city installed a huge nickel-cadmium battery, the same technology used for years in laptop computers and other portable devices.

Housed in a giant warehouse, the 1,300-metric ton battery is larger than a football field, and can crank out 40 million watts of power. Still, the Fairbanks battery provides only enough electricity for about 12,000 residents for seven minutes. That was enough to prevent 81 blackouts in the city in the battery's first two years of operation.

Yet effective storage of electricity from solar or wind arrays that generate power equivalent to one large coal plant implies batteries on a breathtaking scale — hundreds of units the size of the Fairbanks array.

One possible answer? In Japan, so-called "flow" batteries have been used for years to store backup power at industrial plants. Conventional batteries store energy in chemical form. With flow batteries, charged chemicals are pumped into storage tanks, allowing still more chemical to be charged and pumped away, then pumped back into the active portion of the battery and drawn down as needed. One big advantage: Battery "size" can be expanded by simply adding more chemicals and more storage tanks. In 2003, the local utility on small King Island, off the coast of Australia, installed a large flow battery to sop up and later release excess power from a wind farm.

Cost will be key for determining which battery or other storage technologies prevail.

As with the alternative generation technologies, cost will be key for determining which battery or other storage technologies might prevail. Aside from such typical economic concerns as raw material and maintenance costs and durability, storage technologies all face some losses in "round-trip efficiency." Inevitably, some energy is lost as it goes into storage, and more is lost as it comes out.

Right now, hopes are riding high on lithium ion batteries, because they have impressive round-trip efficiencies, can pack in high densities of energy, and can charge and discharge thousands of times before becoming degraded. Because of those attributes, lithium-ion battery technology has become increasingly dominant in laptop computers and cell phones. On a far larger scale, a powerful lithium ion battery pack powers the pricey all-electric Tesla Roadster, and is slated to power the plug-in hybrid Chevy Volt next year.

On the grid, lithium ion experiments are already underway. One company, General Electric-backed A123 Systems, announced late in 2008 that it had been contracted to install a two-megawatt lithium ion storage unit at a California power plant owned by global utility giant AES.

Still, lithium ion remains a relatively expensive technology — 10 times more expensive than lead acid batteries with equivalent capacity. Technological improvements and manufacturing scale should bring lithium costs down over time, but by the time that happens, the world could be beating a path to the door of someone who's found a way to build an even better battery.

Early this year, IBM revealed that it was launching a major research program into what looks like an even more promising technology — the lithium metal-air battery. Last month, a company called PolyPlus announced that it had already succeeded in developing one.

The PolyPlus battery and the IBM technology deliver an astonishing 10 times more energy density than even today's best lithium ion technology. That means that, pound for pound, they offer about the energy density of gasoline. The key reason they can store so much energy is that they use oxygen, drawn from the air, in place of some of the chemical reactants used along with lithium in their lithium ion cousins.

There's one big rub: Air isn't just oxygen. Notably, it also contains humidity, and the lithium has a bad habit of acting like ignited gasoline when exposed to moisture, creating a real risk of fire and explosion.

The stored power in electric cars, or anywhere on the grid, might not come from batteries after all.

Chandrasekhar Narayan, manager of science and technology at IBM's Almaden Research Center near San Jose, Calif., has suggested that it will take five to 10 years to develop an effective membrane that will let oxygen into the battery while keeping moisture out.

Still in pie-in-sky mode, there's "vehicle to grid" storage, or "carbitrage." This enticing notion relies on idled storage in the batteries of the millions of plug-in hybrid or all-electric automobiles that will be in use in the future. There's reason to believe this scheme could work. More than 90 percent of the time cars sit idled, and aside from days they're used for long trips, most of their full energy storage capacity goes unused.

A single idle, electric-powered car could generate as much as 10 kilowatts of power, enough to meet the average demand of 10 houses, according to Willett Kempton, director of the Center for Carbon-free Power Integration at the University of Delaware. With vehicle-to-grid technology, controlled by an array of smart meters, car owners plugged in at home or work could allow the grid to draw off unused chunks of power at times when short-term demand is high. Conversely, cars could be recharged when demand is low.

The stored power in those electric cars, or anywhere on the grid, might not come from batteries after all. In March, Texas-based EEStor announced that it had received third-party verification of its "ultracapacitor" technology. The company claims the lightweight device, which was awarded a U.S. patent last December, can bottle up huge amounts of electricity far more quickly than any battery and can do so at lower cost.

Like batteries, capacitors store and mete out electricity. Small conventional capacitors have been ubiquitous in electronic devices as far back as the early days of radio. But capacitors, so far, haven't been able to store electricity for long enough to come close to competing with batteries. They have found use as devices that level out fluctuations in voltage or that briefly store power for near-instant release.

EEStor claims that its device, which is one-quarter the weight of a similar lithium ion battery, can hold a large charge for days. Its patent describes a 281-pound device that would hold almost the same charge as a half-ton lithium ion battery pack installed on the Tesla Roadster. The company's ultracapacitors have yet to prove themselves in commercial products. But industrial giant Lockheed Martin has already signed up with EEStor to use future ultra capacitors in defense applications, and Toronto-based Zenn Motors, which has also taken an ownership stake in EEStor, says it will have electric cars on the road using the technology in 2010.

Donna Coveney/MIT
Work being done by Daniel Nocera at MIT could open up the possibly that electricity could be stored by splitting (and later recombining) abundant water molecules.

If advanced batteries or ultracapacitors aren't the ultimate answer, maybe using excess electricity to make hydrogen that can be stored will do the trick. Hydrogen can be produced through simple electrolysis, but technical and cost hurdles have made electrolysis impractical. Today, industrial-scale hydrogen is produced using natural gas as a not-so-clean feedstock.

But that may have begun to change last summer when MIT announced that a team lead by chemist Daniel Nocera had made a "major discovery" that employs a new kind of catalyst using cobalt and phosphate — abundant and non-toxic materials — to kick-start electrolysis.

Outside observers say the process could be revolutionary: opening up the possibility that electricity made at any time by the sun or wind could be stored by simply splitting (and later recombining) abundant water molecules, perhaps even undrinkable sea water. The breakthrough has been hailed by scientist British scientist James Barber of Imperial College London as having "enormous implications for the future prosperity of humankind." The website Xconomy reported in April that Nocera had quietly formed a startup company called Sun Catalytics. Efforts to reach Nocera for comment were unsuccessful.

And there is progress being made on an entirely different front — using excess electricity to pump compressed air into caverns, salt domes, and old natural gas wells, and then releasing the air to help state-of-the-art natural gas power plants spin turbines, lowering the amount of fuel consumed by as much as 70 percent. A consortium of utilities in Iowa, Minnesota, and the Dakotas is already working with the U.S.'s Sandia National Laboratories to develop a giant, 268-megawatt compressed air system. Called the Iowa Stored Energy Park, it would store excess energy from the region's burgeoning wind industry.

POSTED ON 13 JUL 2009 IN

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Jon R. Luoma, a contributing editor at *Audubon*, has written about environmental and science topics for *The New York Times*, and for such magazines as *National Geographic* and *Discover*. His third book, *The Hidden Forest: Biography of an Ecosystem*, has been released in a new edition by Oregon State University Press. In previous articles for *Yale Environment 360*, he wrote about new technologies to harness the power of the ocean and how jatropha has failed to emerge as the miracle biofuel that many had predicted it would become.