Battery Research Aims To Store Renewable Energy

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A battery storage facility on Long Island helps to provide power for an MTA bus depot. Credit: New York Power Authority

The biggest chemical battery in the United States is located near Interstate 90 in the small town of Luverne, Minn. The 80 ton device -- the size of two tractor-trailers stacked on top of each other -- stores as much energy as about 3 million rechargeable AA batteries and can power about 3,000 houses for more than an hour when discharging at its maximum rate.

The battery, purchased by utility company Xcel, draws its power from energy generated by a local wind farm. As it charges and discharges, the storage device helps to regulate the power production fluctuations of the wind turbines that feed energy onto the electrical grid.

The battery is also intended to soak up extra energy at night, when the wind blows strongest and when the power demand from the grid is the lowest. This energy can then be released in the afternoon to lessen the strain on the electrical grid when people return home from work.

"We believe that energy storage will allow more wind resources and more renewable sources of power to come on to the system," said Frank Novachek, director of corporate planning for Xcel.

The Department of Energy agrees that massive energy storage will be important, announcing on Oct. 26 the first round of stimulus funds allocated for the development of new high-risk energy technologies. A relatively new DOE agency, the Advanced Research Projects Agency-Energy -- created in 2007 in the image of the Department of Defense's DARPA -- is giving out almost $20 million for the development of new battery chemistries for large-scale storage. These cutting-edge ideas for improved batteries include nanotubes capable of releasing huge amounts of energy in a short amount of time and batteries consisting entirely of liquid metals and molten salt.

Why Size Matters

"Most of the batteries we have in the world were made for small-scale usage," said George Crabtree director of the material science division of Argonne National Laboratory. "You don't need much energy to start your car, and your car battery is going to recharge again as soon as the car starts."

But according to a 2008 report by the American Institute of Chemical Engineers, large-scale batteries need to be developed to deal with the increasing amounts of renewable energy on the grid. The AIChE report warned that no proven technologies have been developed to store large quantities of solar and wind energy.

These renewable sources of energy are not as constant as traditional sources like coal and nuclear power -- winds change speed frequently, the sun does not shine at night, and, as a result, energy must be captured and stored so it can be used when needed. Large-scale, high capacity batteries can allow power companies to constantly adjust and balance the amount of power flowing into the grid to match customer's ever-changing demands.

Coal and nuclear power companies match supply to demand by keeping about 13 percent of the total power supply in reserve. When more power is needed, they can bring more generators online or tap into the reserve.

Because renewable energy sources still make up only a small fraction of the nation's total energy supply -- about 2.4 percent as of 2006 -- their power fluctuations are still manageable. But 26 states have established standards to massively increase the amount of renewable energy. New York state hopes to produce 24 percent of its energy portfolio from renewable sources by 2013; California is shooting for 33 percent by 2020, and Hawaii hopes to achieve 40 percent by 2030.

"Without [massive energy storage], renewable power can only be piggybacked onto the U.S. grid to supply not more than 15 percent of the power at best," concluded the 2008 AIChE report.

Some of the power and storage needs can be provided by technologies other than chemical batteries.

The Tennessee Valley Authority has been using the 1,600 foot Raccoon Mountain to store energy since the 1970s. When the demand for electricity is low, surplus power is used to pump water from a low-lying reservoir to another reservoir at the top of the mountain. When the demand for energy is high and electricity production expenses increase, the water in the upper reservoir is released, and gravity pulls it down a tunnel in the center of the mountain to spin turbines connected to the hydro-electric generator below. The technology is efficient, but additional development of new plants is hampered by environmental concerns and by the lack of suitable mountains in convenient places.

In Alabama, PowerSouth has set up a different kind of storage system that also makes use of natural topography to store energy. The Compressed Air Energy Storage facility in McIntosh forces air into a sealed underground salt cavern the size of an 80 story building. The air can be released and heated to rotate generators and produce electricity. A major limitation of this technology is that it needs to be built in an area containing specific geological formations that will not leak.

Flywheels that spin 15,000 times a minute, developed by Beacon Power in Massachusetts, provide another way of regulating the flow of power. On Nov. 23, construction will begin on a 20-megawatt facility that stores and dispenses power using the mechanical energy of spinning wheels set into motion by a extra electricity. Unlike the large batteries, the wheels cannot hold energy for a long period of time because friction slows them down, but they work well for smoothing out power fluctuations.

Sale on batteries

Chemical batteries do not rely on features of the local landscape and offer longer-term energy storage, making them an attractive option for use as energy storage repositories in the future. Efforts are underway to develop new battery chemistries that range from creating advanced version of lead batteries to improving the capabilities of the lithium-ion batteries that currently power laptops and hybrid cars.

Today's biggest batteries -- including the one in Minnesota and a device intended for emergency power in Texas by the utility company American Electric Power -- are made by the Japanese ceramics company

NGK Insulators. Incentives for renewable power offered by the island nation have led to the installation of NGK's largest battery, more than five times bigger than the Minnesota battery.

The chemistry inside these sodium-sulfur batteries is similar to that of the lead acid battery inside of a car. In the car battery, a chemical reaction provides power by sending electrons from one lead plate to another through a liquid called an electrolyte. NGK batteries replace the lead plates with molten sulfur and molten salt and the liquid electrolyte with a solid piece of ceramic that allows electrons to flow between the two hot liquids.

This gives the batteries a much longer lifetime than car battery chemistry would allow. NGK guarantees them for 15 years (4,500 charge and discharge cycles), during which their efficiency at absorbing and discharging energy drops from about 92 to 75 percent.

But experts agree that sodium-sulfur batteries are still too expensive to affordably achieve the gigawatts of energy storage that will be needed to reach state goals.

"The first thing we need to do is to lower the price of battery systems," said Imre Gyuk, manager for the DOE Energy Storage Research Program. "We also need to increase the cycle life of these systems and improve their reliability."

ARPA-E's new awards are focused on price-cutting technologies in early stages of development.

Battery manufacturer EaglePicher, working in partnership with the Pacific Northwest National Laboratory, received $7.2 million to modify the sodium sulfur batteries. The researchers are hoping to lower the operating temperature and slow down the corrosion that limits battery life by thinning the ceramic plate that separates the components inside.

"PNL has already made prototype separators that reduce the operating temperature by 100 degrees Celsius [180 degrees Fahrenheit]," said Robert Higgins, director of new technology at Eagle Picher. "[The battery] will have a longer lifetime and a much lower cost."

Dan Sadoway of the Massachusetts Institute of Technology in Cambridge, Mass., received about $7 million on the strength of a prototype battery the size of an ink bottle that works in an entirely different way. His all-liquid device eschews expensive materials in favor of cheap metals like magnesium and antimony. The design operates around 1,300 degrees Fahrenheit, sandwiching a layer of molten salt between two layers of liquid metals.

Another ARPA-E award went to the FastCAP Systems Corporation, also located in Cambridge, Mass., which designs capacitors -- devices that store less energy than batteries but are able to release that energy much faster. FastCAP is working on increasing the surface area of capacitors to create ultracapacitors that could contain more electrical charge and store more energy. Their goal is to produce a device with the same energy density and energy storage capacities as batteries that would be capable of releasing power 20 times more effectively. An additional advantage of capacitor technology over battery technology is in their use of materials that are less toxic and available domestically.

"With ARPA-E, we are swinging from the heels and trying to hit home runs, not just base hits," Energy Secretary Steven Chu said. "This is high-risk, high reward research: if even one or two of these ideas become transformative technologies -- the next transistor or another Green Revolution -- this will be among the best investments we've ever made."