

## New flow battery offers lower-cost energy storage

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PNNL researcher Xiaoliang Wei prepares a small demonstration organic flow battery. Credit: Pacific Northwest National Laboratoyr

Energy storage system owners could see significant savings from a new flow battery technology that is projected to cost 60 percent less than today's standard flow batteries.

The organic aqueous flow <u>battery</u>, described in a paper published in the journal *Advanced Energy Materials*, is expected to cost \$180 per kilowatt-hour once the technology is fully developed. The lower cost is due to the battery's active materials being inexpensive organic molecules, compared to the commodity metals used in today's flow batteries.

"Moving from transition metal elements to synthesized molecules is a significant advancement because it links battery costs to manufacturing rather than commodity metals pricing" said Imre Gyuk, energy storage program manager for the Department of Energy's Office of Electricity Delivery and Energy Reliability (OE), which funded this research.

"The battery's water-based liquid electrolytes are also designed to be a drop-in replacement for current flow battery systems," said PNNL materials scientist Wei Wang, one of the paper's corresponding authors. "Current flow battery owners can keep their existing infrastructure, drain their more expensive electrolytes and replace them with PNNL's electrolytes."

## **Changing currents**

Flow batteries generate power by pumping liquids from external tanks



into a central stack. The tanks contain liquid electrolytes that store energy. When energy is needed, pumps move the electrolytes from both tanks into the stack where electricity is produced by an electrochemical reaction.

Both flow and solid batteries, such as the <u>lithium-ion batteries</u> that power most electric vehicles and smartphones today, were invente¬¬¬d in the 1970s. Lithium-ion batteries can carry much more energy in a smaller space, making them ideal for mobile uses. The technology gained market acceptance quickly, for both mobile uses like cell phones and larger, stationary uses like supporting the power grid.

Lithium-ion batteries now make up about 70 percent of the world's working, grid-connected batteries, according to data from DOE-OE's Global Energy Storage Database. However issues with performance, safety and lifespan can limit the technology's use for stationary <u>energy</u> <u>storage</u>.

Flow batteries, on the other hand, store their active chemicals separately until power is needed, greatly reducing safety concerns. Vanadium-based flow batteries have become more popular in recent years, especially after PNNL developed a new vanadium battery design in 2011 that increased storage capacity by 70 percent. Three different companies have licensed the technology behind PNNL's vanadium design.

Nearly 79 percent of the world's working flow batteries are vanadiumbased, according to data from the Global Energy Storage Database. While vanadium chemistries are expected to be the standard for some time, future flow battery cost reductions will require less expensive alternatives such as organics.

## **Tried & tested**



PNNL's new flow battery features two main electrolytes: a methyl viologen anolyte (negative electrolyte) and a 4-hydroxy-2,2,6,6-tetramethylpiperidin-1-oxyl, or 4-HO-TEMPO catholyte (positive electrolyte). A third, supporting electrolyte carries sodium chloride, whose chloride ions enable the battery to discharge electricity by shuffling electrons in the central stack.

"Using readily available materials makes our all-organic aqueous <u>flow</u> <u>battery</u> more sustainable and environmentally friendly. As a result, it can also make the renewable <u>energy</u> it stores and the power grid it supports greener," Wei said.

To test the new battery design, Wang and his colleagues created a small, 600-milliwatt battery on a lab countertop. They repeatedly charged and then discharged the battery at various electric current densities, ranging from 20 to 100 milliAmperes per square centimeter. The test battery's optimal performance was between 40 and 50 milliAmperes per square centimeter, where about 70 percent of the battery's original voltage was retained. They also found the battery continued to operate well beyond 100 cycles.

Next, the team plans to make a larger version of their test battery that is able to store up to 5 kilowatts of electricity, which could support the peak load of a typical U.S. home. Other ongoing efforts include improving the battery's cycling so it can retain more of its storage capacity longer.

**More information:** Tianbiao Liu, Xiaoliang Wei, Zimin Nie, Vincent Sprenkle, Wei Wang, "A Total Organic Aqueous Redox Flow Battery Employing Low Cost and Sustainable Methyl Viologen (MV) Anolyte and 4-HO-TEMPO Catholoyte," *Advanced Energy Materials*, Nov. 30, 2015, <u>DOI: 10.1002/aenm.201501449</u>.



## Provided by Pacific Northwest National Laboratory

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