WHITE PAPER

Investment Drives Interest in Flow Batteries and Long-Duration Energy Storage

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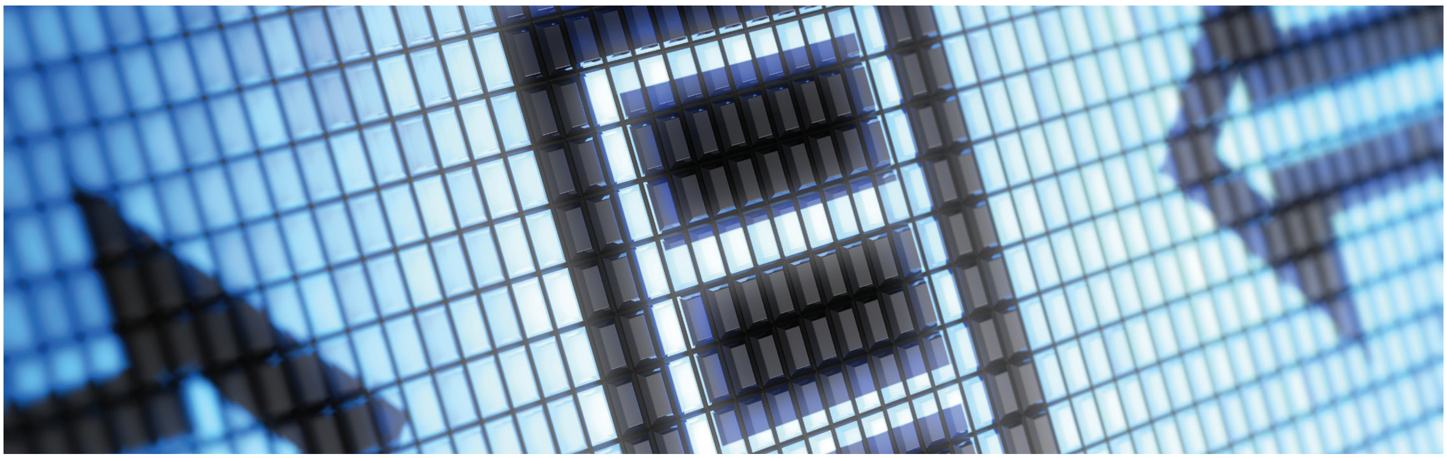
The commercialization of next-generation long-duration energy storage may get a boost in the U.S. with the expected passage of bipartisan infrastructure legislation that includes more than $500 million for energy storage demonstrations. For companies investing in flow batteries and other longer-duration technologies, it couldn't come at a better time.



Demand for flow batteries and other long-duration energy storage technologies is growing, even if their current cost does not yet make them competitive in the commercial market. Interest should only increase as the industry closes coal-fired power plants, brings more renewable energy resources online and seeks ways to manage the resulting imbalances between energy production and demand.

But a decarbonized grid isn't the only issue driving interest in long-duration storage technologies. As the February 2021 winter storms in Texas demonstrated, the grid is not fail-safe. Disasters — natural and otherwise — can cause major power outages that put human lives in danger. When these events happen, stored energy can be a true lifesaver.

In fact, the state of California is already taking action. To address the state's well-documented energy needs, the California Energy Commission is supporting a massive investment in energy storage to manage the generation supply curve.

Electrification programs create further demand for stored energy. As more electric vehicles take to the streets, long-duration solutions can be used to help power charging stations. Elsewhere, companies like Microsoft and Google expect long-duration technologies to play an important role in their pledges to shift data centers from net zero carbon initiatives — where carbon offsets counterbalance emissions — to zero carbon initiatives that depend on 100% carbon-free energy.

Flow batteries — rechargeable fuel cells that store chemical energy in external tanks instead of within the battery proper — are seen by many as the next-generation alternative to the lithium-ion batteries now commonly used for energy storage. Depending on their chemistry, flow batteries can ramp up quickly, cycle multiple times a day, provide longer service — easily eight or more hours — and have up to 30 years of usable life if properly maintained. Many flow batteries are also being developed with modularized systems with an eye for scaling up solutions to utility scale. The liquid electrolytes they use to charge and discharge also pose little or no fire risk.

In sum, flow battery technology can deliver products with good performance and capacity. Reports on some vanadium flow batteries show only a 1% drop in energy storage capacity after 10 years of use.

Still, multiple barriers — most notably, high production costs and few financial incentives — have limited the application of the emerging longer-duration battery storage technologies now entering the market. New federal funding for demonstration flow battery projects may do for flow batteries what electric vehicle research and development did for lithium-ion.

In the meantime, the industry remains fluid. Disruption created by COVID-19 led some manufacturers to return to their research labs, where they focused on increasing electrolyte energy density. While some energy storage companies struggle to stay afloat, others have consolidated, merging supply chains and acquiring patents that may deliver competitive advantages.

For example, Largo Clean Energy, a manufacturer of vanadium redox flow batteries, acquired VionX Energy Corp. and is now commercializing the flow battery technology VionX previously owned. Largo Clean Energy reports plans to establish 1.4 gigawatt-hours (GWh) of annual battery stack manufacturing capacity at a new plant in Massachusetts.

Similarly, Lockheed Martin and Oriden LLC announced a teaming agreement in 2020 for future energy storage projects using Lockheed Martin's flow battery technology. Two other flow battery providers — RedT Energy and Avalon Battery — merged in 2020 to form Invinity Energy Systems. Meanwhile, iron electrolyte flow battery company ESS Inc. announced plans in May 2021 to go public.

The State Of Play

These companies join at least a dozen others around the world vying for their breakout moment. Each is depending on one or more of about 12 different chemistries that appear ready for commercial applications. However, only a handful of these chemistries — vanadium, zinc-bromine and iron — are currently being used in utility-scale applications.

Vanadium Redox Flow Batteries

Perhaps most common is the vanadium redox flow battery, which relies on vanadium's ability to exist in four different oxidation states, each of which has a different electrical charge. When the battery is discharged, ion exchange between the electrolyte and stack generates electricity. Vanadium redox flow batteries do not suffer from degradation like lithium alternatives, meaning that they do not require augmentation to maintain the same power output. Vanadium can also be easily recycled at the end of the project, making this battery a sustainable option.

At least five companies are applying vanadium redox flow battery technology in their long-duration storage solutions. These companies include Invinity, which reported that its battery costs dropped by up to 30% following the RedT and Avalon merger. The small modular design of the company's revamped product is said to benefit from RedT's processing and manufacturing experience and the system-level technology and modularization that Avalon contributed.

Austria-based CellCube, which reports having completed more than 130 energy storage installations worldwide, also relies on vanadium redox flow battery technology. Its projects are expected to ramp up production to 240 megawatt-hours (MWh) in 2022. Meanwhile, VRB Energy announced plans in 2021 to build a 100-megawatt (MW) solar photovoltaic and 100-MW/500-MWh vanadium redox flow battery integrated power station in China.

Other players in the vanadium redox flow battery space include Sumitomo Electric and WattJoule.

Zinc-Based Flow Batteries

Multiple other long-duration solutions rely on zinc-bromine batteries, a hybrid redox flow battery that stores energy by plating zinc metal onto the anode plates in the electrochemical stack during charge. Originally developed by Exxon in the 1970s, zinc-bromine batteries have among the highest energy densities found in flow batteries. Consider, for example, Primus Power, which designs and develops grid-scale electrical energy storage and battery technology solutions using zinc-bromine flow batteries.

Founded in 2009, it has been shipping its small modular designs to both U.S. and international microgrid and utility customers.

On the other side of the world, in Australia, Redflow has developed one of the world's smallest zinc-bromine flow batteries. The company is now focused on simplifying its manufacturing and reconfiguring for mass production, changes it says should reduce battery costs by a third. It will soon be deploying its first flow battery in the U.S. at a 2-MWh waste-to-energy facility in California.

Two other companies — Zinc8 Energy Solutions and NantEnergy — have developed technologies that employ rechargeable zinc-air batteries that are powered by oxidizing zinc. While not a flow battery, Eos Energy Enterprises also has a rechargeable battery that utilizes zinc chemistry. These high energy density batteries are relatively inexpensive to produce.

Eos reports a backlog of $30 million and booked energy storage orders with Hecate Energy, Azure Power and ZGlobal Inc. Zinc8 raised $15.5 million in early 2021 to fund continued product development after signing an agreement with New York Power Authority to deploy a 100-kilowatt (kW)/1-MWh battery energy storage system to support peak shaving at the University of Buffalo.

Iron Flow Batteries

A third type of long-duration storage, iron flow batteries, uses electrolytes composed of ionized iron salts to store electrical energy as chemical energy. Because iron is abundant and nontoxic, this solution has the potential to reduce the cost of energy storage.

It is also where startups like Form Energy are placing their bets for long-duration storage. Backed by Bill Gates' Breakthrough Energy, Form Energy introduced a new iron-air battery in August 2021 that can deliver power for 100 hours at one-tenth the cost of lithium-ion. Because of the low-cost materials, Form Energy reports that its washing machine-sized batteries cost just $20 per kilowatt-hour (kWh), compared to the $50 to $80 per kWh cost of lithium-ion batteries.

Form Energy, launched in early 2021, also relies on iron flow battery technology. The energy storage system starts at 3 MW power capacity but can be scaled up for larger projects. In more recent months, ESS has announced a contract to integrate 300 kW/2 MWh of its technology into a solar microgrid in rural Chile. ESS is expected to use proceeds from its merger with a special purpose acquisition company to create 16 GWh of manufacturing capacity on three continents.

More New Chemistries On The Horizon

Additional flow battery companies and chemistries continue to enter the market. For example, researchers at Warwick University in the U.K. say they have found a way to make a redox flow battery that costs less than $25/kWh. According to ScienceDaily, the redox flow battery technology combines carbon-based electrodes with low-cost manganese or sulfur electrolytes using an electrophoretic deposition of nitrogen-doped graphene additives. The combination is said to significantly enhance electrode durability and performance in highly acidic or alkaline environments.

Meanwhile, Cyclotron Road, a division of the Lawrence Berkeley National Laboratory, has been awarded $3 million in seed funding for a carbon-oxygen flow battery technology it developed. The lightweight, low-cost technology has demonstrated lab-scale proof of concept, and researchers are now working to scale it up to a stack-level demonstration.

Elsewhere in the U.S., flow battery installations have been limited primarily to pilot projects and grant-funded deployments at the utility or state level. For example, the California Energy Commission is helping to fund a handful of microgrids and other Invinity Energy Systems projects designed to provide communities with backup power and lower energy costs.

Adiabatic compressed air energy storage, pressurized liquid air energy storage and other mechanical energy storage systems, along with thermal and gravitational energy storage systems, may also be promising alternatives for bulk electricity storage. Each deserves its own discussion. Given manufacturer efforts to lower their materials and production costs, at least some of these solutions may become price-competitive and commercially viable. Funding from the U.S. infrastructure plan, if passed, may help kick-start the effort.

For the electric grid and those who depend on it, one thing is certain: Now is the time for utilities to begin exploring how long-duration storage might fit within their integrated resources plans.

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