Sodium-Beta Batteries

Improving the performance and reducing the cost of sodium-beta batteries for large-scale energy storage

U.S. DEPARTMENT OF ENERGY | Electricity Delivery & Energy Reliability

Energy Storage Program

Pacific Northwest National Laboratory

Sodium-beta batteries (Na-beta batteries or NBBs) use a solid beta-alumina (β''-Al_2O_3) electrolyte membrane that selectively allows sodium ion transport between a positive electrode (e.g., a metal halide) and a negative sodium electrode. NBBs typically operate at temperatures near 350°C. They are increasingly used in renewable storage and utility applications due to their high round-trip efficiency, high energy densities, and energy storage capacities ranging from a few kilowatt-hours to multiple megawatt-hours. In fact, U.S. utilities have installed more than 9 MW of NBBs for various grid-scale applications, with another 9 MW in development.

However, current NBBs do not discharge stored electrochemical energy efficiently. In addition, their relatively high operating temperatures pose challenges for materials selection and durability, making the existing technology too expensive for broad market penetration.

Overview

The Office of Electricity Delivery and Energy Reliability's (OE's) Energy Storage Program is funding research to further develop a novel planar design for NBBs that will improve energy and power densities and simplify manufacturing. This project will demonstrate a planar prototype that operates at <300°C and will scale up the storage capacity to 5 kW, improving on the performance levels being pursued in a related battery research project conducted by EaglePicher Technologies, LLC; Pacific Northwest National Laboratory (PNNL); and the Advanced Research Projects Agency—Energy (ARPA-e).

Objectives

- Reduce operating temperature to <250°C in order to lower materials costs, increase cycle life, and reduce thermal management issues
- Employ a thinner electrolyte to decrease resistance and a planar design to create a larger active surface area that can achieve higher power and energy densities
- Optimize electrode chemistries and interfaces to improve electrochemical activity
- Improve seals and casings to reduce cost

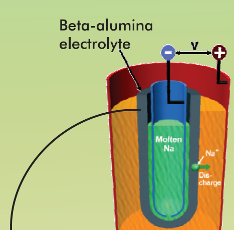
Potential Technology Benefits

- Offers a 30% higher energy density and 100% higher power density due to increased active area per volume and decreased diffusion distances
- Enables production of scalable, modular batteries at 50% of the cost of today's tubular designs using inexpensive construction materials and manufacturing techniques
- Operates at a lower temperature than traditional NBBs, increasing battery life
- Enables manufacturing based on abundant, inexpensive materials
- Offers high round-trip efficiency and long cycle life
- Produces no emissions during operation, due to a completely sealed design
- Enables recycling of 99% of the battery materials; only sodium must be handled as a hazardous metal

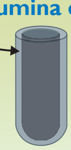
Technology Breakthrough

Current sodium-beta batteries (NBBs) use thick tubular beta-alumina electrolytes that pass sodium between the anode and the cathode. Researchers at Pacific Northwest National Laboratory (PNNL) have designed an NBB that uses a planar beta-alumina electrolyte to increase the active area and decrease the diffusion distance in the battery. These improvements increase NBB power output by 30%. The planar NBBs can then be stacked, instead of bundled together, to achieve grid-scale energy storage.

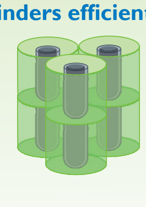
The Current Technology



Uses a cylinder-shaped beta-alumina electrolyte

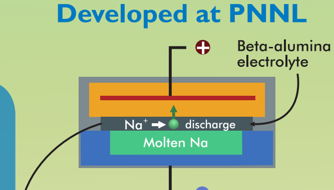


That hinders efficient scale-up



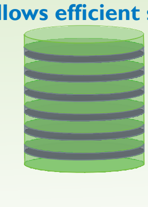
For the same size system, the PNNL research has shown a 30% improvement in power output.

Technology Being Developed at PNNL



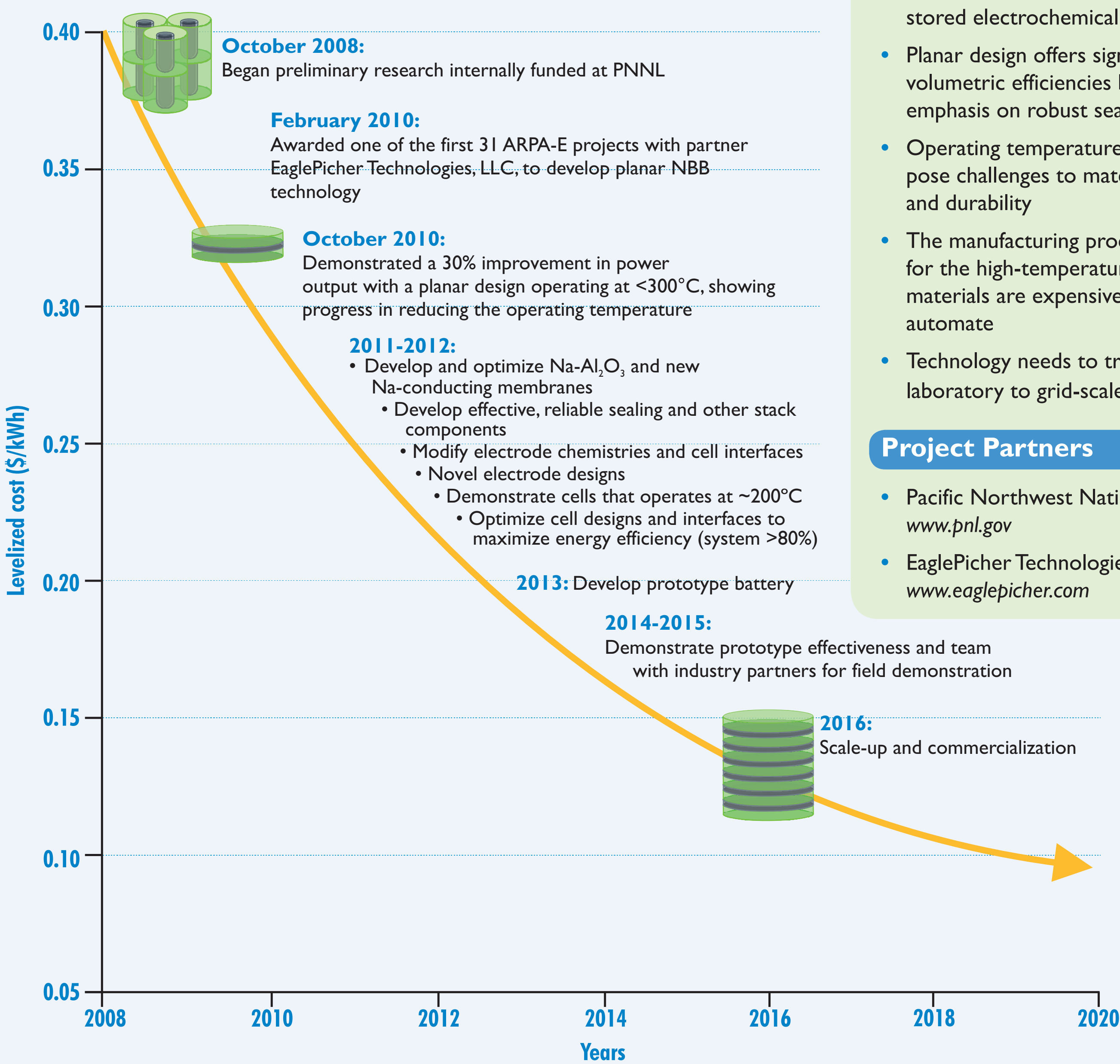
Uses a planar beta-alumina electrolyte

That allows efficient stacking



Project Timeline

Ongoing research and development will reduce the costs of NBBs.



Challenges

- Current technology's cylindrical shape does not allow efficient discharge of stored electrochemical energy
- Planar design offers significant volumetric efficiencies but places added emphasis on robust seal development
- Operating temperatures near 350°C pose challenges to materials selection and durability
- The manufacturing processes required for the high-temperature casing materials are expensive and difficult to automate
- Technology needs to transition from laboratory to grid-scale deployment

Project Partners

- Pacific Northwest National Laboratory
  www.pnl.gov
- EaglePicher Technologies, LLC
  www.eaglepicher.com

For More Information

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Related Reading

Pacific Northwest National Laboratory, "Affordability of batteries key to harnessing wind and solar power," http://www.pnl.gov/news/release.aspx?id=849.

Pacific Northwest National Laboratory "Planar Power," http://materials.pnl.gov/news/planar.stm.

Sandia National Laboratories, "Energy Storage Systems Program (ESS)," http://www.sandia.gov/ess/.

Importance of Energy Storage

Large-scale, low-cost energy storage is needed to improve the reliability, resiliency, and efficiency of next-generation power grids. Energy storage can reduce power fluctuations, enhance system flexibility, and enable the storage and dispatch of electricity generated by variable renewable energy sources such as wind, solar, and water power. The Office of Electricity Delivery and Energy Reliability Energy Storage Program funds applied research, device development, bench and field testing, and analysis to help improve the performance and reduce the cost of energy storage technologies.

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