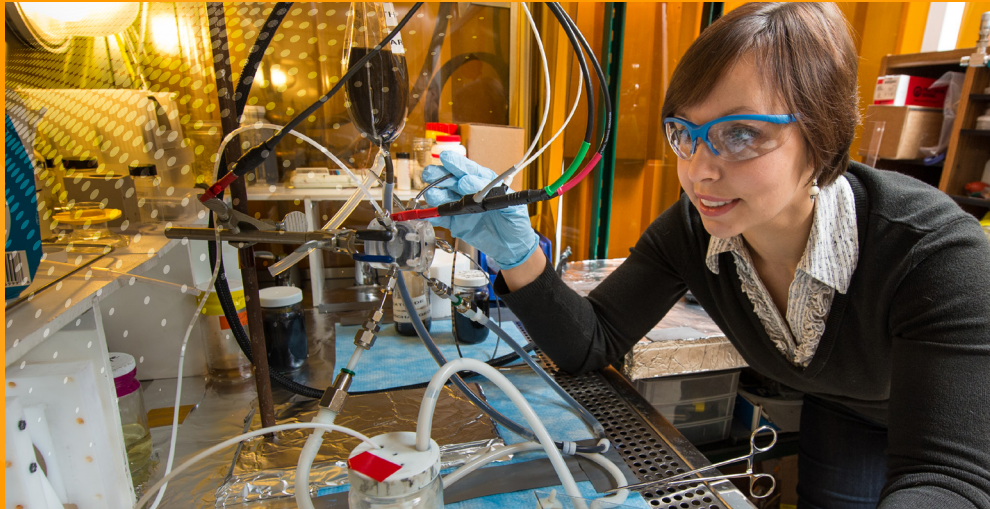


Rechargeable Nanoelectrofuels[™] for Flow Batteries

Groundbreaking energy storage concept
may revolutionize the world of batteries

**UNIQUE FLOW BATTERY-
NANOFLUID COMBINATION
OFFERS PROPERTIES UNLIKE
THOSE FOUND IN CONVENTIONAL
SOLID BATTERIES**



TINY YET POWERFUL PARTICLES

Although still in its early stages, nanotechnology is opening vast new territories for discovery and innovation. Scientists recently found, for example, that the unique properties of liquids known as nanofluids, which contain nanoscale particles in suspension, make them ideal candidates for a host of industrial and consumer applications.

Working together, scientists from Argonne National Laboratory and the Illinois Institute of Technology (IIT) have developed a groundbreaking concept for the storage of electrical energy. Leveraging the properties of nanofluid technology and flow

batteries, the team created a rechargeable battery in liquid form, whose convenience is comparable to that of gasoline. The battery design employs Nanoelectrofuel™— a unique liquid in which tiny battery-active particles are permanently suspended and can be charged and discharged multiple times in a customized flow battery cell. Operating at significantly greater capacity than conventional flow batteries, the Nanoelectrofuel battery offers a host of other benefits, among them thermal safety, lower cost, higher efficiency, flexibility and adaptability. The use of the high-energy-density Nanoelectrofuel offers fertile ground for scientific exploration across many disciplines and promises to revolutionize the practice of energy storage.

NANOELECTROFUELS EXCEED CRITICAL PERFORMANCE FACTORS FOR ENERGY STORAGE

Attribute	Stationary Power	Transportation	Nanoelectrofuel
Cost per kWh	Less than \$100 needed	Less than \$250 needed	\$80
Energy density	25 – 35 Wh/kg	Up to 200 Wh/kg	Up to 600 Wh/kg

A HIGHLY FLEXIBLE SYSTEM

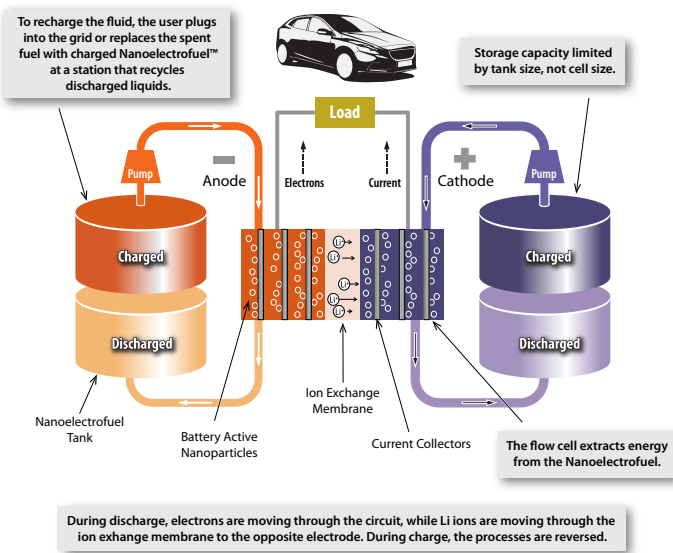
The unique flow battery–Nanoelectrofuel combination offers properties unlike those found in conventional solid batteries, providing an attractive alternative for any industry or application that relies on energy storage for its operations.

The stability and low cost of this cutting-edge innovation make it a good choice for numerous interchangeable industrial design applications, particularly the following:

- ▶ Transportation (rechargeable liquid form of batteries for electrical and hybrid electrical vehicles, fast refueling, zero emissions)
- ▶ Stationary power storage (battery systems for large-scale load-leveling and local house back-up systems), including
 - Renewables (efficient storage and distribution of energy from intermittent wind and solar plants)
 - Military devices (concentrated energy, fast response, easy maintenance)

HOW IT WORKS

This innovation in battery technology provides a key advantage over conventional batteries: its energy-storing material—that is, the Nanoelectrofuel—can be separated from its charging device, the flow cell. For example, Nanoelectrofuels can be charged at solar plant locations and transported to market by specially designed trucks or by rail. The fuel can be deployed in a variety of uses such as fueling an electric vehicle or power tool, supplying electricity to homes and more. To recharge the fluid, the user plugs into the grid or replaces the spent fuel with charged Nanoelectrofuel at a station that recycles discharged liquids.



Taking advantage of Nanoelectrofuel's unique properties, the flow cell design can be easily optimized by adjusting such variables as the size and composition of the nanoparticles and the size and shape of the flow cell materials. The Nanoelectrofuel can be stored externally to the flow cell and charged or discharged while passing through the cell in a closed circuit. Novel flow-through cells use inexpensive conductive materials.

The battery system itself is highly flexible: Nanoelectrofuel storage tanks of any shape or size can be used, and can be positioned as desired with respect to the flow-cell stack. In electric vehicles, this is particularly important. Currently, electric vehicles must be “designed around” the battery's requirements. Flow batteries with Nanoelectrofuel, on the other hand, can be located virtually anywhere in an electric vehicle and in any shape—enabling a storage tank to be placed, for example, in the safest place in case of collision.



KEY BENEFITS

SAFETY

Battery safety in electric vehicles is a key concern. The superior heat transfer capabilities of Nanoelectrofuel make flow batteries an eminently safer choice for electric vehicles than those currently in use.

DESIGN FLEXIBILITY

The system lends itself to an almost infinite number of design options. It offers variable power and energy density ratings with storage tanks of any shape positioned however needed with respect to the flow cell stack.

HIGH ENERGY DENSITY

Nanoelectrofuel-powered flow batteries offer a capacity more than 10 times greater than conventional flow batteries.

EFFICIENT, RESPONSIVE

Nanoelectrofuels exhibit fast response, high charge/discharge efficiency and an extended fuel cycle life.

TRANSPORTABLE

Pumpable and chemically stable, Nanoelectrofuel is easily distributed.

SMALLER FOOTPRINT

Nanoelectrofuel enables powerful stationary installations on an order-of-magnitude smaller footprint.

ECONOMICAL TO PRODUCE

Nanoelectrofuels can be manufactured domestically without complex factory assembly or sealed packaging.

ENVIRONMENTALLY FRIENDLY

Rechargeable liquid Nanoelectrofuels are recyclable and sustainable with zero emissions. The technology offers an easy way to separate electrode materials from other battery components for disposal or recycling.

RESEARCH WINS \$3.44M ARPA-E GRANT

The Argonne/IIT team has won a three-year, \$3.44 million grant from Advanced Research Projects Agency-Energy (ARPA-E), a government agency that funds research and development of advanced energy technologies. The award was one of 22 granted to projects across 15 states focused on innovations in transformative electric vehicle energy storage. The funding will allow the construction of a 1 kWh Nanoelectrofuel™ flow battery prototype scalable for electric vehicle needs.

DEVELOPMENTAL STAGE

This technology is available for licensing.

FOR MORE INFORMATION, CONTACT

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Argonne National Laboratory is a U.S. Department of Energy laboratory managed by UChicago Argonne, LLC.

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