Rechargeable Nanoelectrofuel Flow Batteries

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Flow Batteries

Traditional RedOx Flow Batteries (RFB) – Chemicals Dissolved in Electrolyte

Pros:
- Active material in external tank
- Charging apart from the battery
- Decouples Energy and Power ratings
- Almost unlimited cycles (lifetime)
- Safety

Cons:
- low salt solubility in electrolyte => low energy density
- ~ 40 Wh/L or 30 Wh/kg

Nanoelectrofuel flow battery up to 70% of solids => more than 10 times of energy density

Transportation Requires Higher Energy Density than Traditional RFB
Energy Storage Landscape

Format Change:

**Nanoelectrofuel Flow Battery**
- High Energy Density
- Pumpable
- Transportable
- Design Flexibility
- Smaller Footprint
- Efficient
- Responsive
- Economical To Produce
- Safe
- Environmentally Friendly

![Energy Storage Landscape Diagram](image)
Nanoelectrofuel Flow Battery

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.

Storage capacity limited by tank size, not cell size.

The flow cell extracts energy from the Nanoelectrofuels.

During discharge, electrons are moving through the circuit, while Li ions are moving through the ion exchange membrane to the opposite electrode. During charge, the processes are reversed.
Fourier transformed x-ray absorption spectra for intermetallic anode nanoparticles show that similar changes to the structure occur when nanoparticles are lithiated in conventional coin cell assembly (left) and in nanofluid flow cell (right). SEM image shows sizes of anode particle of 50-300 nm.
ARPA-E RANGE award: $3.44M to IIT/Argonne team to build nanoelectrofuel flow battery prototype: 1 kWh, 40 V, C/3

2014
1. COMSOL simulation of individual cell

2015
1. COMSOL simulation of a prototype
2. Individual cell demonstration

2016
Prototype stack
40 V, 1kWh
Long Term Vision
Nanoelectrofuels

Energy Generation Avenues

Nanoelectrofuels Charging

Rapid pump EV refueling

Charged suspension to markets

Enables V2H macro and micro grid applications

Enables Rate Shifting and Grid Leveling
Gain as many quads as possible for Renewables, and Cleaner Conversions...

- 160,000 Miles of Power Lines in U.S. Electric Grid
- 32% of Industrial Energy for Refining
- 113 Million Homes Use 22% of U.S. Energy
- 77% of Commercial Energy from Electricity

<table>
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<tr>
<th>Supply</th>
<th>Conversion</th>
<th>Consumption</th>
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<tr>
<td>75 Quads Domestic Production</td>
<td>58 Quads Direct Use of Primary Supplies</td>
<td>42 Quads Used Energy</td>
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<td>23 Quads Net Imports</td>
<td>40 Quads Consumed to Generate Electricity</td>
<td>36 Quads Conversion Losses</td>
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<td>Oil 36 Quads</td>
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<td>50% Imported</td>
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<td>Natural Gas 25 Quads</td>
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<td>Coal 21 Quads</td>
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<td>Nuclear 8 Quads</td>
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<td>Residential and Commercial 22 Quads</td>
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<td>Transportation 5.6 Quads</td>
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<tr>
<td>Industry 30 Quads</td>
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