Prototype of Rechargeable Nanoelectrofuel Flow Battery

Team:
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Co-PI: Dr. Elena Timofeeva, Argonne

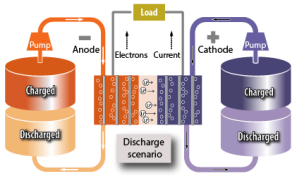
Technology Overview

Approach: Merging solid and flow battery formats with high energy density pump-able nanoelectrofuel electrodes (NEF, > 50 vol.% of cathode and anode nanoparticles stably dispersed in electrolyte).

Using established battery chemistries to demonstrate new battery format.

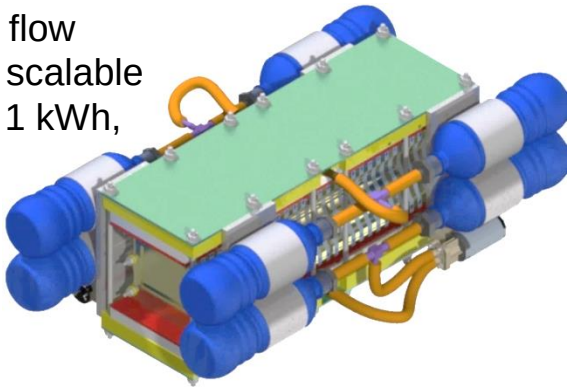
Value Prop: >2x capacity of advanced Pb-acid batteries at ½ cost of Li-ion, with 3 minute charge replenishment

High Energy Density



Pump-able Format

Deliverable: NEF flow battery prototype scalable for EV demands: 1 kWh, 36 V, C/3



Current Status

(1) **STATUS:** demonstrated anodic and cathodic NEFs in half cells.

(2) **NEXT TECHNICAL:** demonstrate full flow through cell with cathode and anode NEFs

(3) **NEXT COMMERCIAL**: secure strategic partner who funds/supports pilot program for Light Utility Electric Vehicles (LUEV)

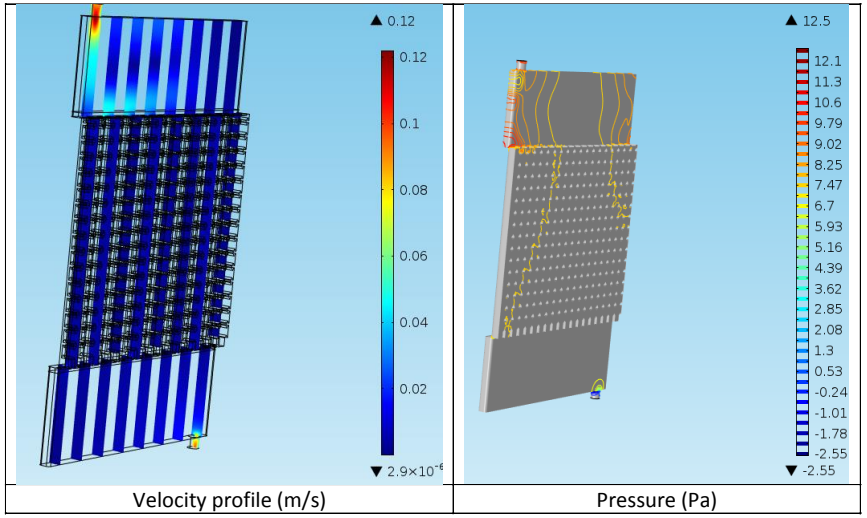
(4) **HELP NEEDED:** Partners for nanomaterial manufacturing, rapid prototyping, licensing technology from Argonne back to start-up

Project Statistics

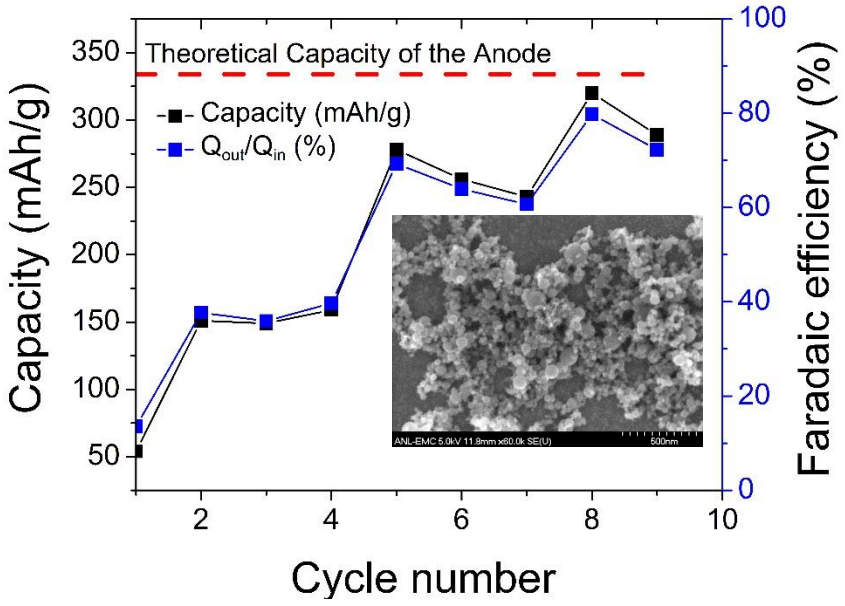
Award Amount	$3.44 M
Award Timeline	Jan. 2014 – Dec. 2016
Next Stage Target	Pilot program for LUEVs 10-20 kWh battery
Collaborations Sought	TBD

Major Accomplishments

- Conceptual design of prototype: system level energy density
  36V@80L >180Wh/L; >73Wh/kg
  36V@200L >210Wh/L; >80Wh/kg
- CFD modelling of individual cells: Viscosity up to 1000cP is acceptable for fairly uniform velocity profile
- Demonstrated charging of nanofluid close to the theoretical capacity in half cell configurations
- Achieved Coulombic efficiency equal to solid casted electrodes with same nanoparticles
- Developed surface modification for nanoparticles that show < 10 cP viscosity at >50 vol.% particle loading and electrochem compatible



Velocity profile (m/s) | Pressure (Pa)



Technology-to-Market

I-Corps™ Energy and Transportation
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NEXTENERGY
ask us what's next

May-June 2014

Learned:

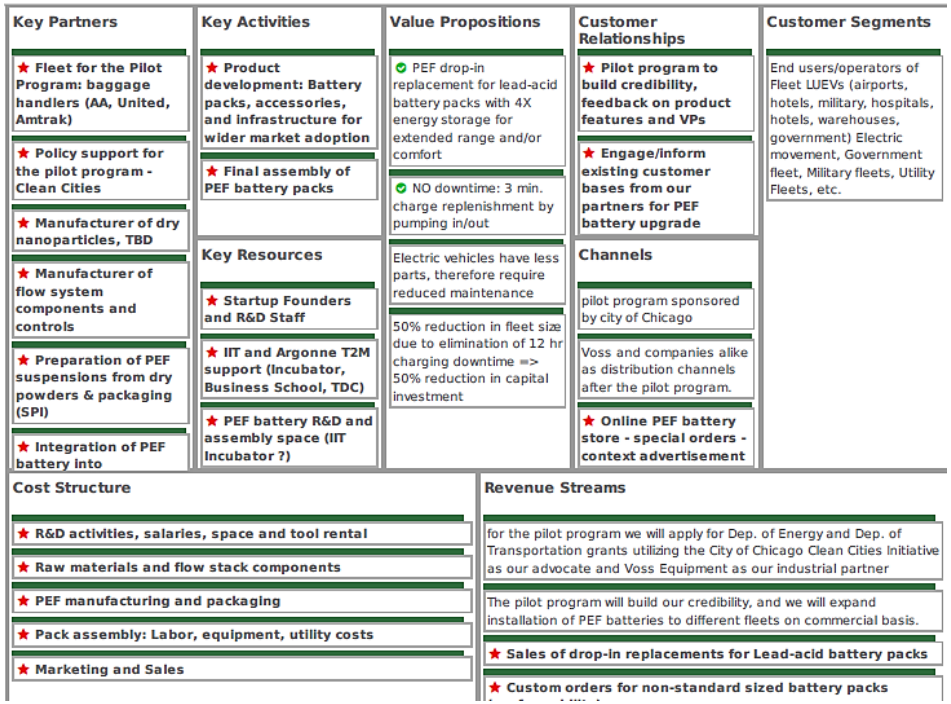
- Importance of Value Proposition
- Customer discovery process
- Business language
- Nuances of EV/OEM world
- Start-up process
- Funding opportunities
- Policies and regulations

Extended the network

Identified path forward as a start-up company

Found prospective partners

Developed Business Canvas



December 2014

Founded "Influit Energy LLC."

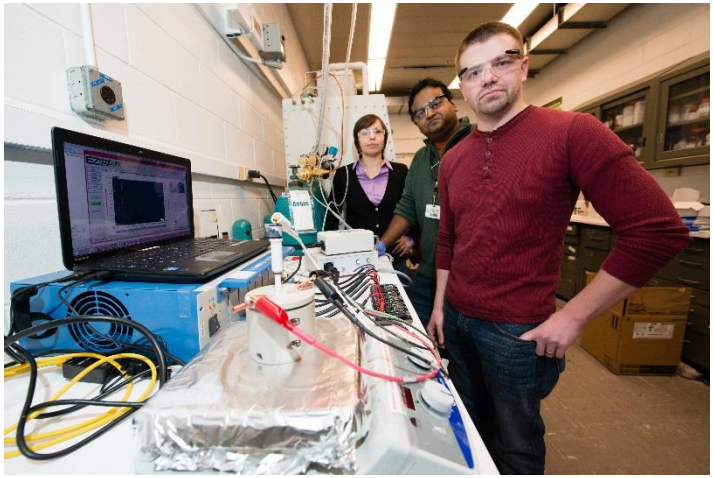
Lessons Learned

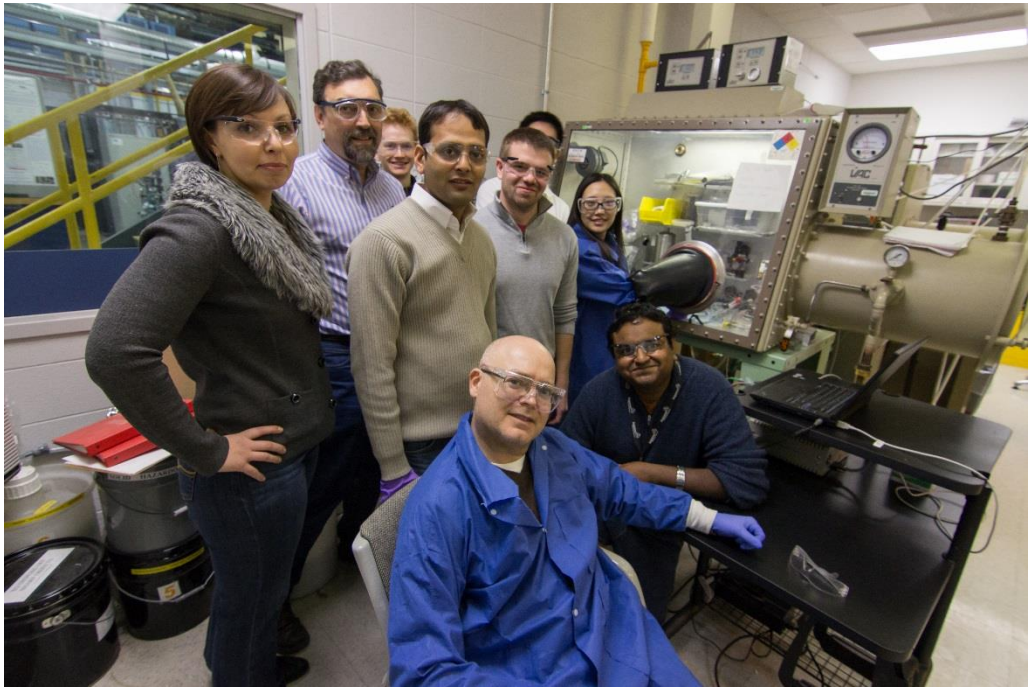
- For large scale storage aqueous and non-aqueous NEF systems show compatible energy density
- Current EV market is not that big
- One of barriers for penetration is need for expensive infrastructure (network of charging stations)
- Game-board for OEMs is huge with internationally connected decision making
- With totally new technologies prototype-to-market for passenger vehicles takes 10-20 years
- OEMs appear to be in favor of incremental improvements, not embracing transformational technologies
- 10-20 years time frame is too long for start-up to survive
- Need smaller stepping stone markets

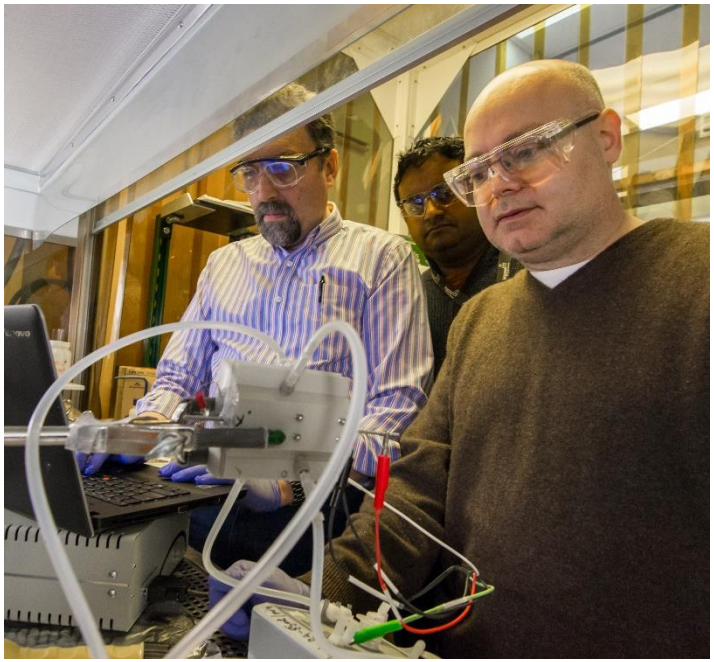
Wanted Collaborations

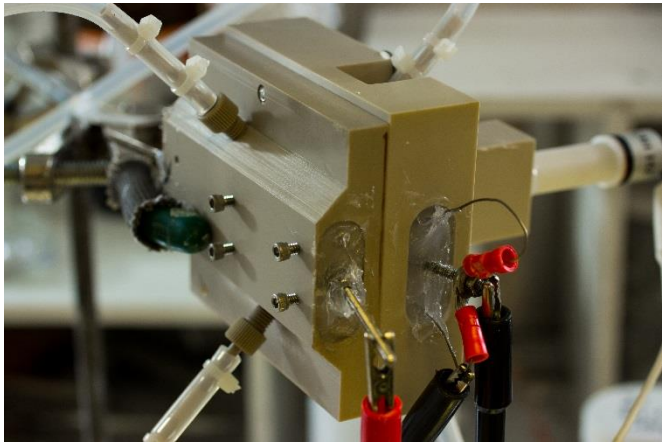
- 3D prototyping companies
- Plastic and metal parts manufacturers
- Nanomaterials manufacturers
- LUEV manufacturers
- LUEV distributors, service providers
- Organizations that use small (10-100) fleets of LUEVs at centralized locations for Pilot Program
- Sponsors for Pilot Program

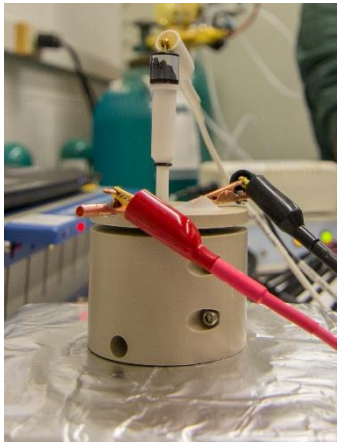
Project Team











Project Team

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News Clips

nofeeva@gmai × ARPA-E awards IIT-Argoni ×

www.anl.gov/articles/arpa-e-awards-iit-argonne-team-34-million-breakthrough-battery-technology

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ARPA-E awards IIT-Argonne team $3.4 million for breakthrough battery technology

AUGUST 30, 2013

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CHICAGO – Carlo Segre, Duchossois Leadership Professor of Physics at Illinois Institute of Technology, has received a $3.4 million award from the U.S. Department of Energy's Advanced Research Projects Agency (ARPA-E) to develop a breakthrough battery technology that may more than double the current range of electric vehicles (EV), increase safety, reduce costs and simplify recharging.

Segre and his collaborators John Katsoudas, also of IIT, and Elena Timofeeva, Dileep Singh and Michael Duoba of Argonne National Laboratory will develop a prototype for a rechargeable "nanoelectrofuel" flow battery that may extend the range of EVs to at least 500 miles and provide a straightforward and rapid method of refueling. Current EV ranges are 100-200 miles, with recharging taking up to eight hours.

Flow batteries, which store chemical energy in external tanks instead of within the battery container, are generally low in energy density and

Researchers (left to right) Dileep Singh, Carlo Segre, Mike Duoba, John Katsoudas, Elena Timofeeva, and Chris Pelliccione stand by one of the plug-in electric vehicles they hope to revolutionize with the IIT-Argonne "nanoelectrofuel" flow battery technology they are developing. Click to enlarge.

CONTACT US

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News from Argonne's Transportation Research Program
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Rechargeable Nanoelectrofuels for Flow Batteries May Revolutionize EV World page 4
Operating at more than 10 times the capacity of a conventional flow battery, the nanoelectrofuel battery promises to revolutionize the practice of energy storage.
Unlocking the Door to Better Diesel Engine Combustion and Emission Performance page 10
A revolutionary advance in our understanding of how diesel engines work may unlock new approaches to predicting diesel engine performance and emissions.
On the cover
Chemist Elena Timofeeva sets up an experiment to evaluate nanoelectrofuel performance.
Shown here
John Katsoudas and Dileep Singh review experimental results from a full flow battery test in the fume hood wet lab area.

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ofeeva@gmai × IIT, Argonne get $3.4M gr ×

www.suntimes.com/news/metro/22342508-418/iit-argonne-get-34m-grant-to-improve-electric-car-battery.html#.VFEnnyLF-So

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IIT, Argonne get $3.4M grant to improve electric-car battery

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BY SANDRA GUY Technology/Higher Education Reporter September 3, 2013 5:40PM

Researchers Dileep Singh (left), Carlo Segre, Mike Duoba, John Katsoudas, Elena Timofeeva and Chris Pelliccione with one of the plug-in electric vehicles they hope to revolutionize with the IIT-Argonne "nanoelectrofuel" flow battery technology they are developing. | Photo courtesy IIT-

Updated: October 5, 2013 6:28AM

Researchers at the Illinois Institute of Technology and Argonne National Laboratory announced Tuesday they have won a $3.4 million federal grant to develop technology that could let electric cars run five times longer on a single charge.

The technology aims to make all-electric cars a more viable choice by allowing

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15 COMMENTS

A Battery with Liquid Electrodes Can Be Recharged or Refilled

ARPA-E is funding several projects that use liquid battery electrodes to cut costs and increase energy density.

By Kevin Bullis on February 17, 2014

Battery tester: Argonne National Laboratory chemist Elena Timofeeva sets up an experiment to test a liquid electrode (seen inside the IV bag).

A new kind of battery stores energy in what researchers are calling "rechargeable fuel"—electrodes in liquid form. The result can be either recharged like a conventional battery or replaced by pumping in new fuel like gasoline.

The materials could theoretically allow an electric car to travel 500 miles on a charge, five times farther than most electric vehicles can now, say the researchers developing the technology, who are based at Argonne National Laboratory and the Illinois Institute of Technology. Replacing them at a fueling station would take just a few minutes. In contrast, even the fastest charging stations for conventional batteries take an hour to provide a full charge.

WHY IT MATTERS

Widespread use of electric vehicles could reduce oil consumption.

Limited driving range and long recharging times are two of the biggest challenges for electric cars. Liquid battery electrodes could allow longer range by increasing the amount of energy battery packs can store, and because fewer non energy storing components would be needed, it could also make them cheaper.