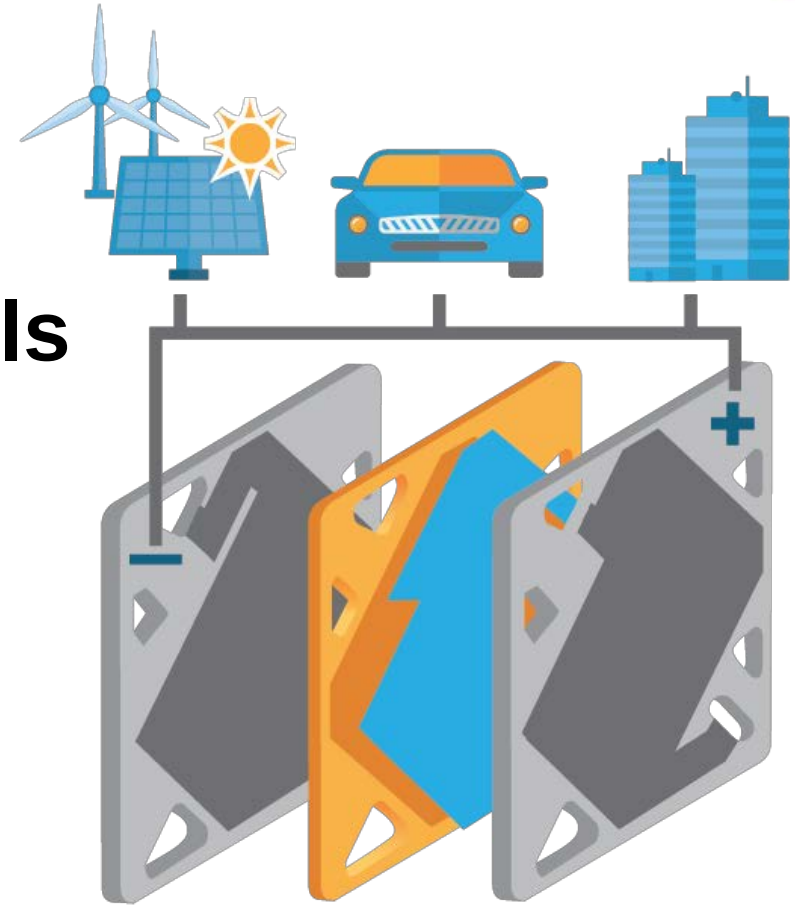
# IONICS: A Solid Foundation for a New Generation of Electrochemical Cells

Paul Albertus, Program Director

February 27, 2017



# Cheap wind, solar, and natural gas are here, now

## Wind

Median cost: 4.7 ¢/kWh

Zero emissions & water, free fuel

## Solar


Median cost: 5.4 ¢/kWh

Zero emissions & water, free fuel

## Natural gas combined cycle

Median cost: 6.3 ¢/kWh

>61% efficient, low emissions



Source for costs: Lazard's Levelized Cost of Energy Analysis – Version 10, 2016.

# Using low-cost, low-emission electricity is challenged

## Primary energy

## Challenges for use of low-cost primary energy

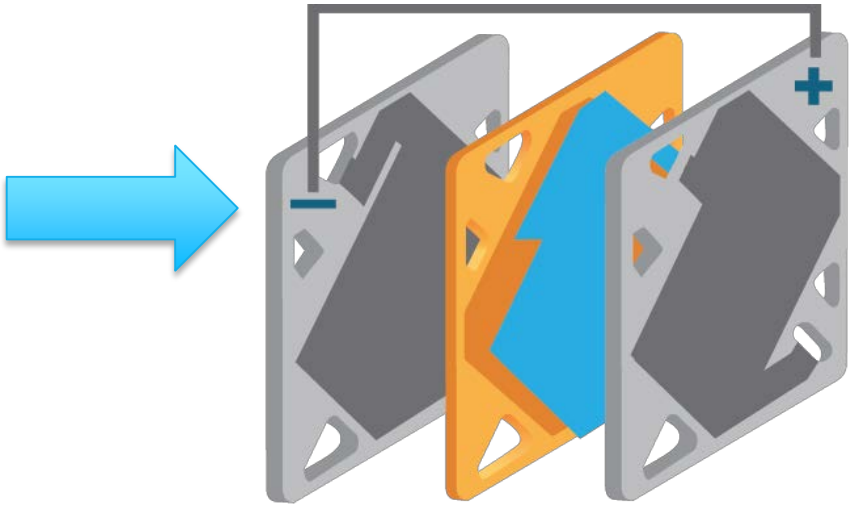
1. Solar and wind are intermittent
2. Transportation batteries are large, heavy
3. Hydrogen fuel cells and electrolyzers need expensive components
4. Natural gas combined cycle slow to start and ramp, lower efficiency at part load

## End uses

# Using low-cost, low-emission electricity is challenged

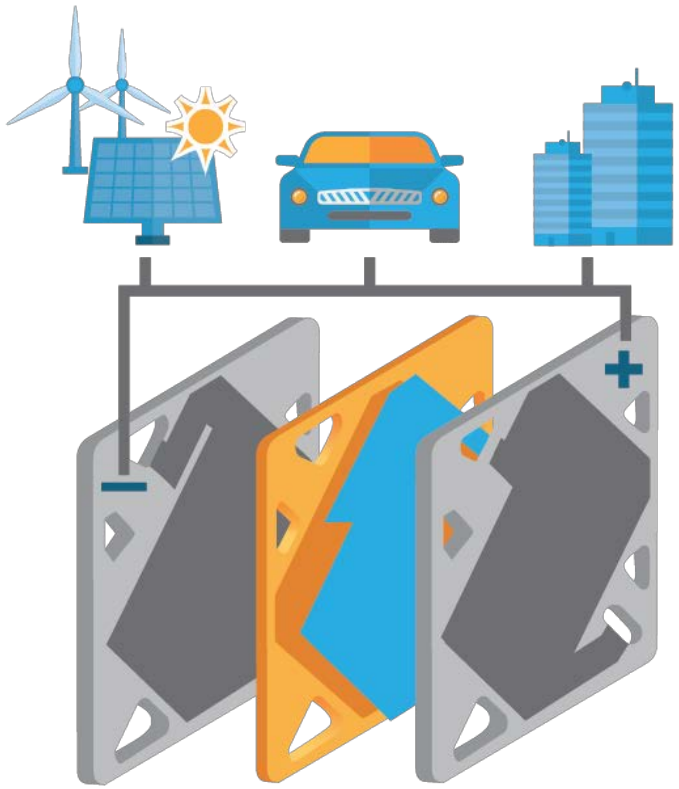
**Primary energy**

ARPA-E IONICS Program



**End uses**

# IONICS is informed by lessons of past programs



**Stationary electrochemical cells**

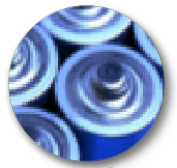
GRIDS

REBELS

METALS

CHARGES

**Transportation electrochemical cells**



BEEST

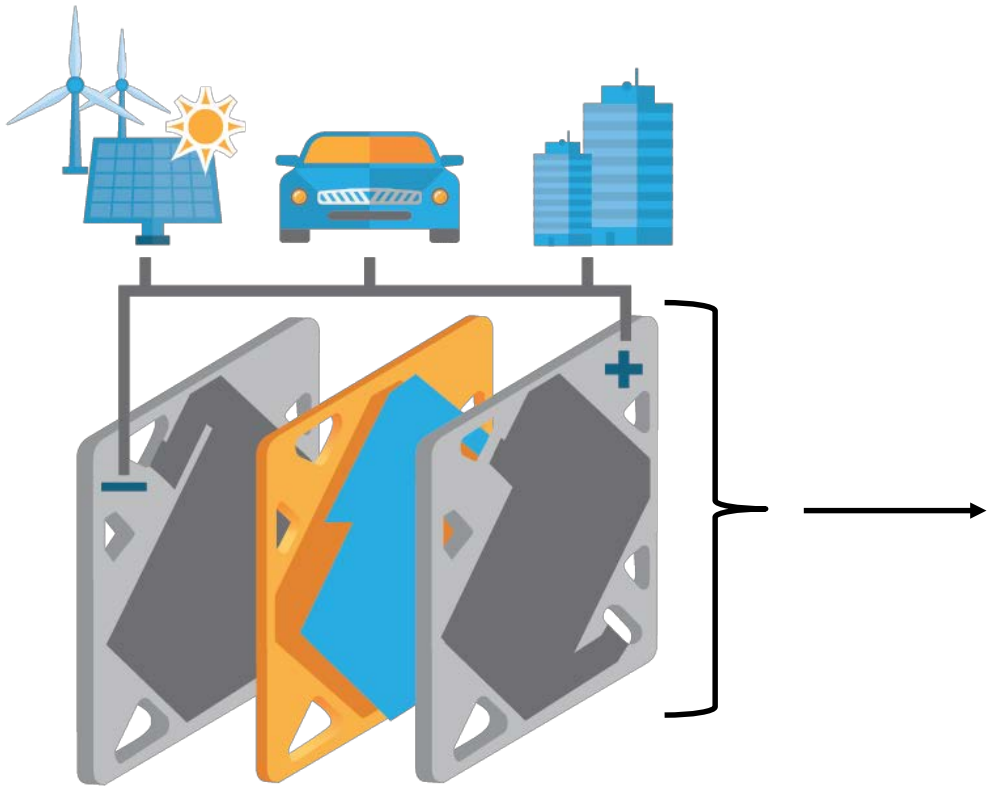
AMPED

RANGE

REFUEL

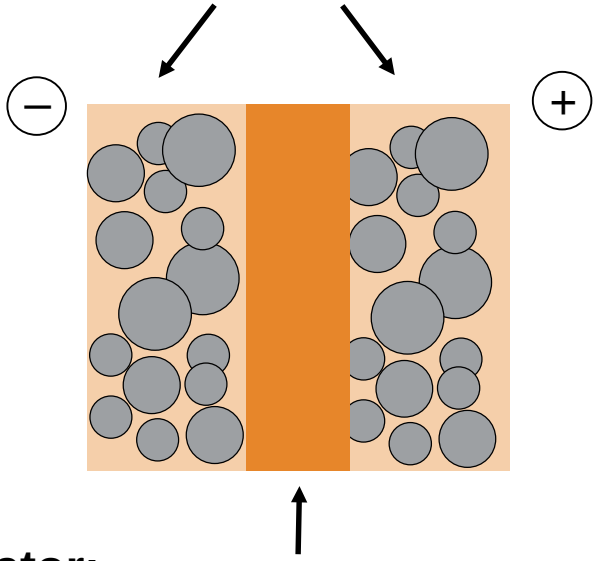
**Lessons on key barriers and enabling components**

# IONICS is focused on separators



**Electrodes:**

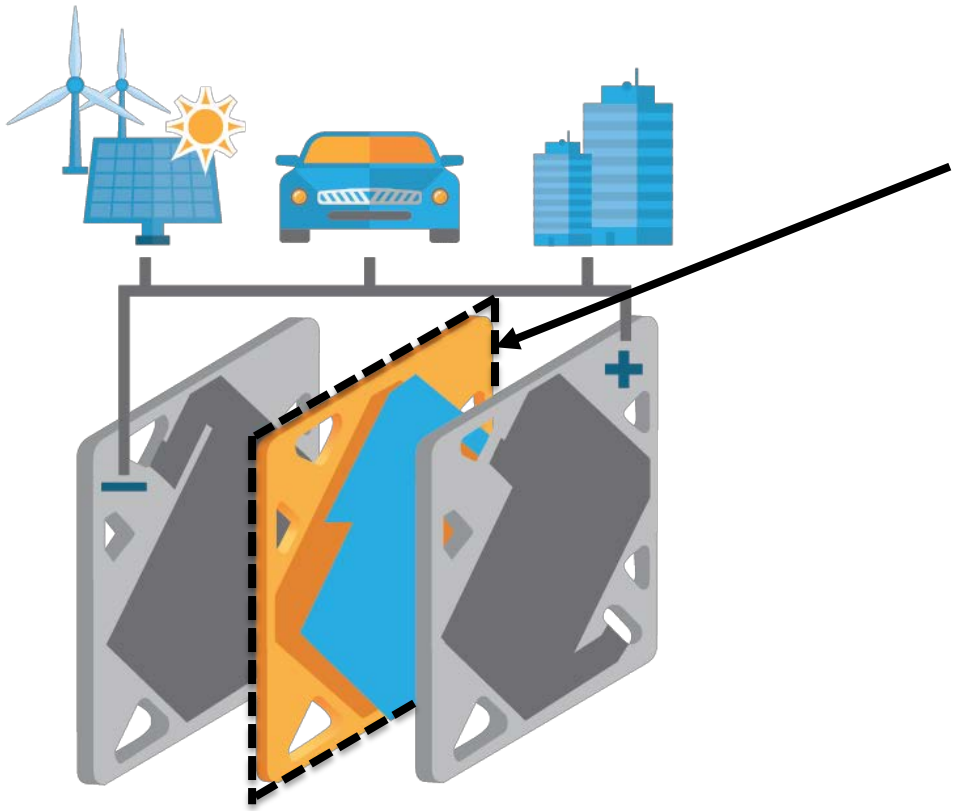
- Couple chemical reactions with electrical energy.
- Many phases for catalysis, charge storage, conducting ions and electrons, etc.




**Separator:**

- Conducts ions, blocks electrons.
- *Determines what electrodes are used.*

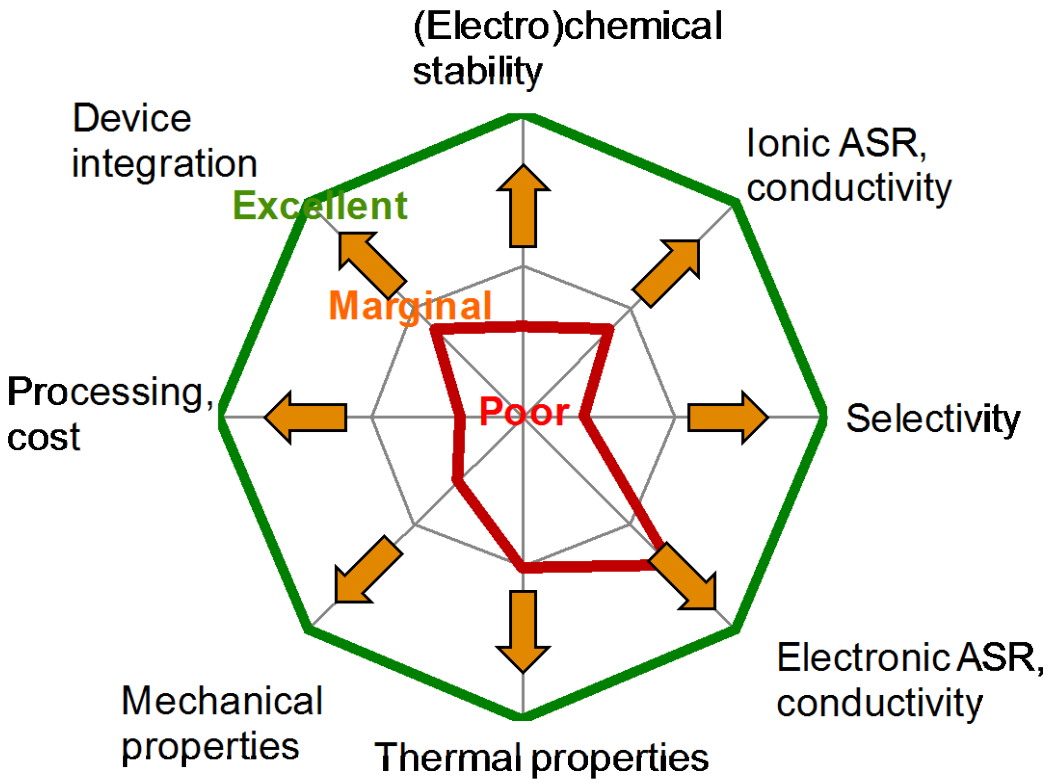
# IONICS is focused on separators with solid ion conductors



## IONICS Program

- Overcome critical gaps in separator performance.
- Pursue *solid* ion conductors for their
  - Mechanical properties
  - Chemical and thermal stability
  - High selectivity

# IONICS is focused on overcoming property tradeoffs




## IONICS Program

- Overcome critical gaps in separator performance
- Pursue *solid* ion conductors for their
  - Mechanical properties
  - Chemical and thermal stability
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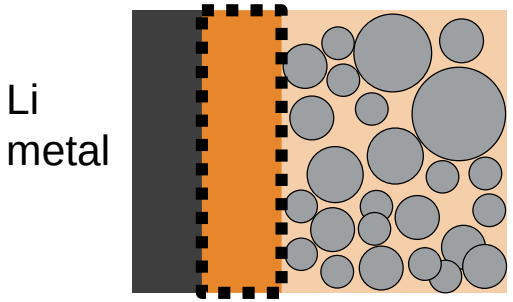
# Category 1: High-energy, Li metal batteries for vehicles

## Problem and Opportunity

Battery pack
450 kg
~$15k
240 miles

Li metal provides >30% more energy, lower cost, better cell safety.

Block dendrites




## Teams

POLY PLUS

ionic MATERIALS

University of Colorado Boulder

SILA NANOTECHNOLOGIES

OAK RIDGE National Laboratory

IOWA STATE UNIVERSITY

24M

PennState

UC San Diego

## Sample approach

$Li^+$-conducting glasses are known to block dendrites (*e.g.*, LiPON).

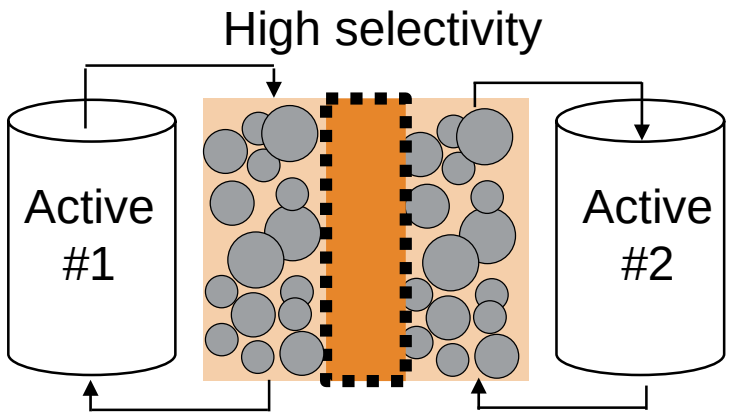
New compositions and processing to make $Li^+$-conducting glasses that are thin and low cost.

# Category 2: Low-cost flow batteries for the grid

## Problem and Opportunity

Li-ion storage costs are 2x above energy time shift cost goal.

Flow batteries have a path to performance and cost goals for energy time shift.




## Teams

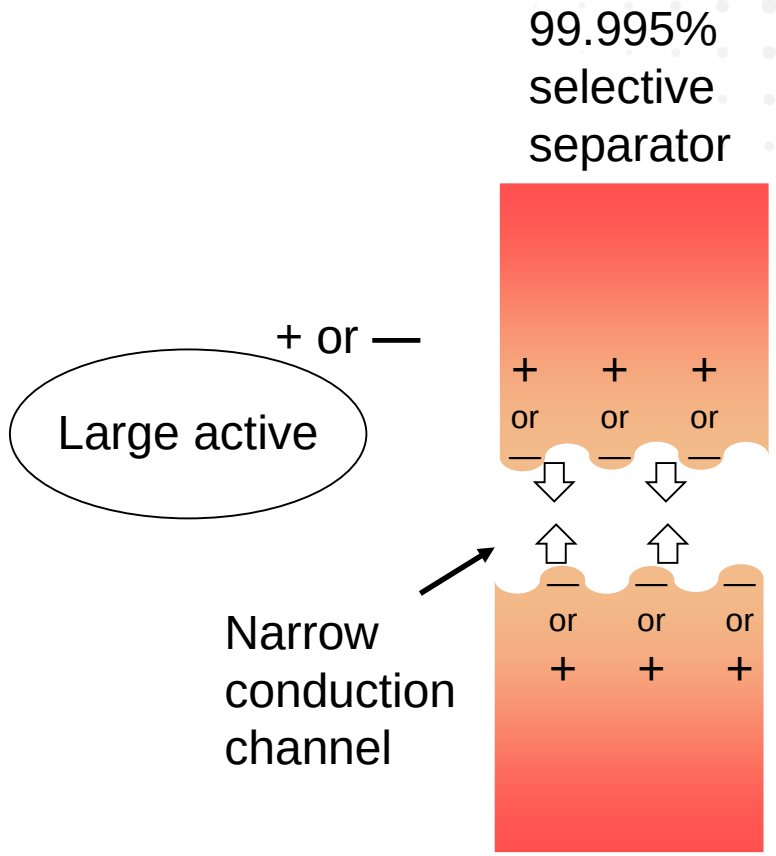
United Technologies Research Center

School of Mines Colorado 1874

Washington University in St. Louis

University of Colorado Boulder

## Sample approach



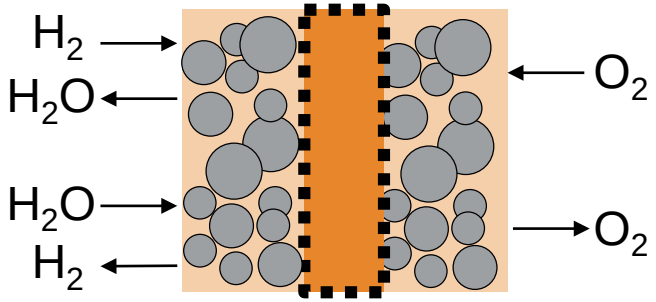
# Category 3: $H_2/O_2$ devices with low-cost catalysts

## Problem and Opportunity

Today's $H_2/O_2$ devices use acid conductors, require expensive catalysts (*e.g.*, Pt).

Alkaline conductors open path to low-cost catalysts, >20% capital cost reduction.

High stability (alkaline)




## Teams

University of Delaware

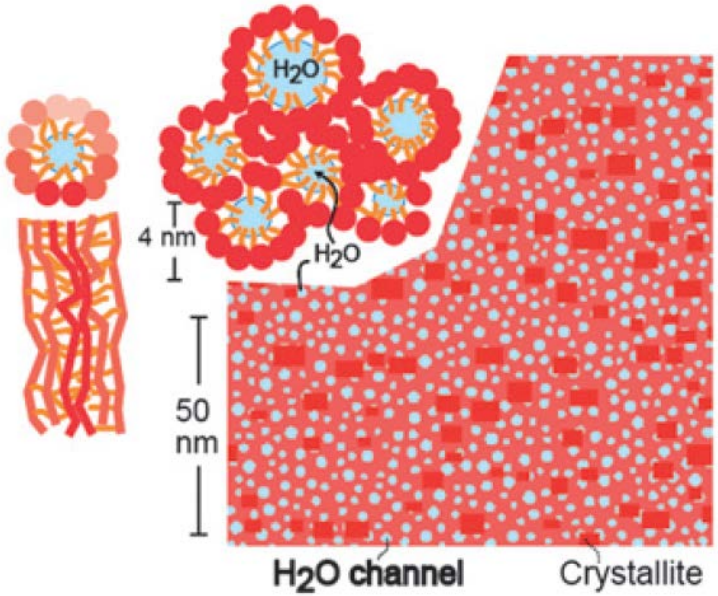
3M

Rensselaer

## Sample approach

Intrinsically stable backbones, tethers, and head groups.

Morphology engineering modeled on Nafion




Klaus Schmidt-Rohr & Qiang Chen, Nature Materials 7, 75 - 83 (2008)

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**Results coming soon!**