ARPA-E grid storage overview

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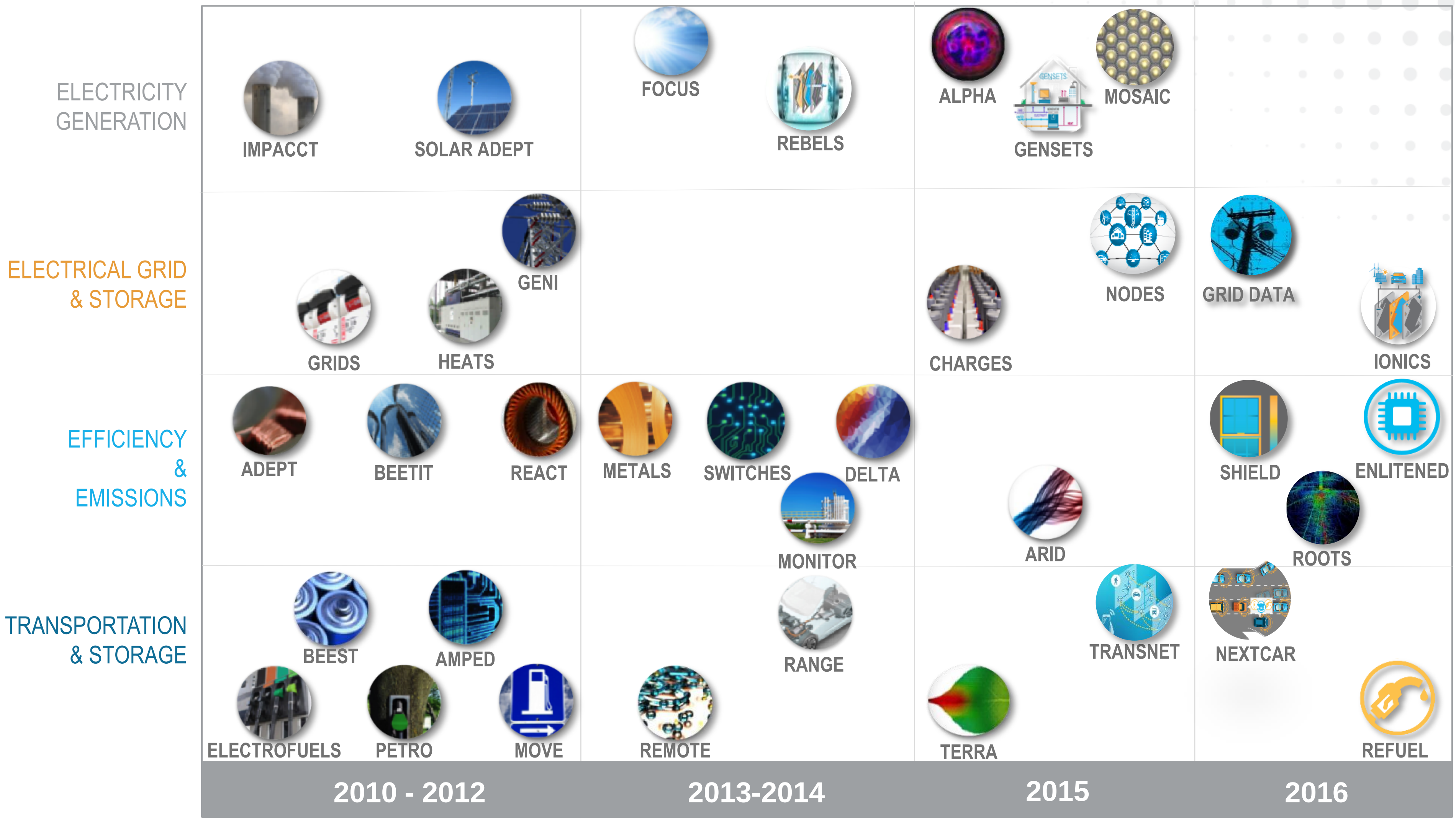
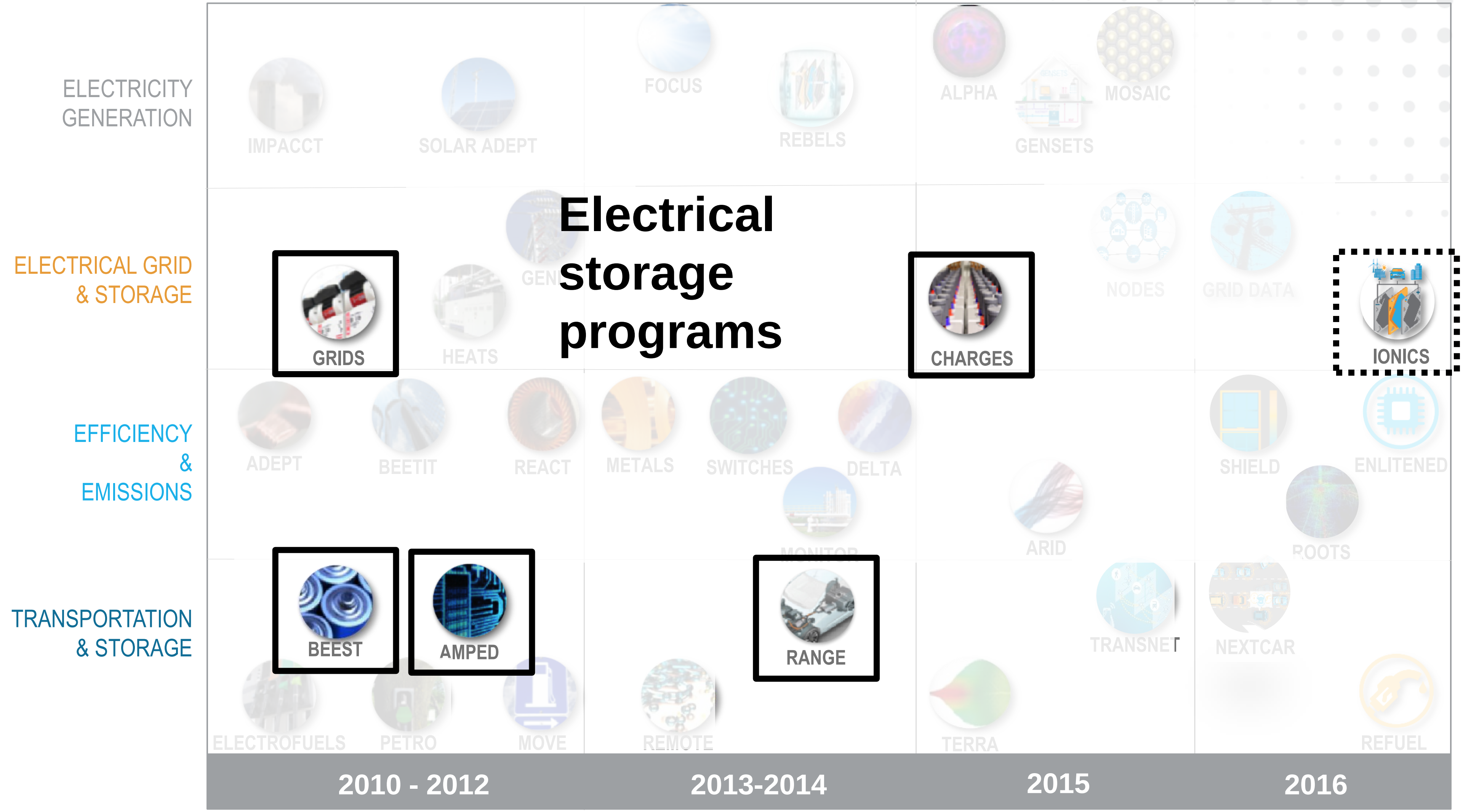
DOE/OE Peer Review, September 26, 2016

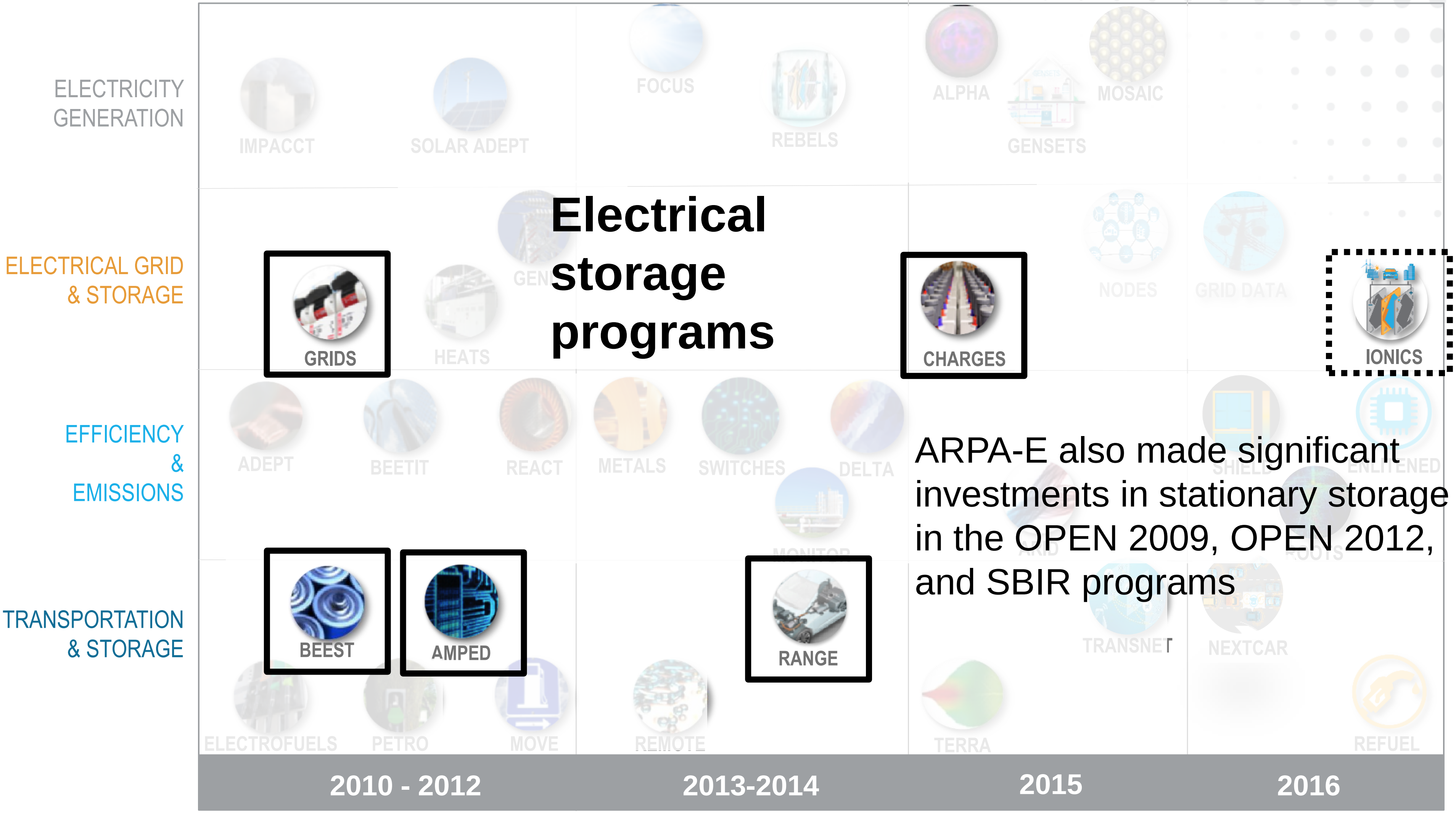
ARPA-E Focused Program Portfolio



ARPA-E Focused Program Portfolio



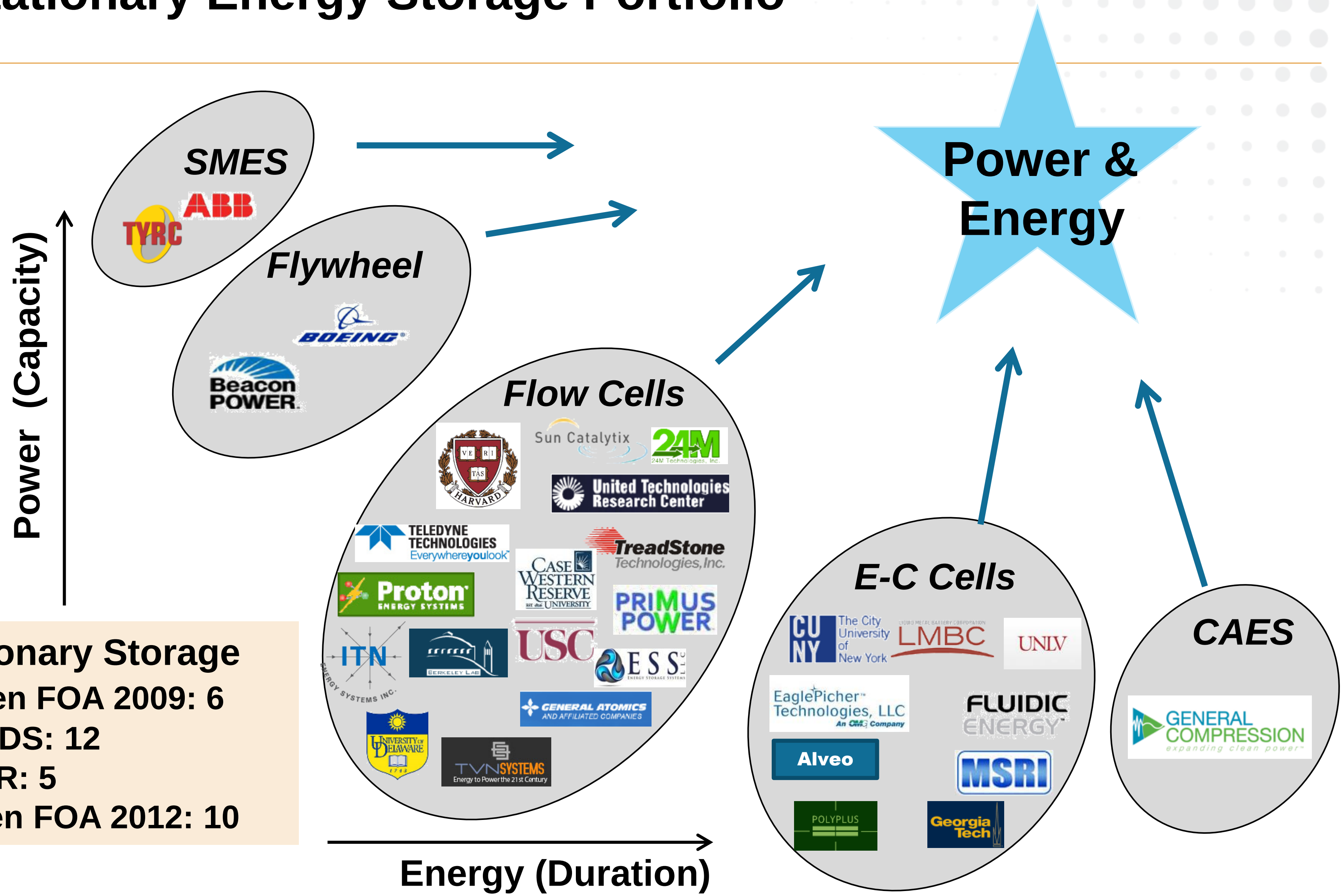
ARPA-E Focused Program Portfolio



Electrical storage programs

ARPA-E also made significant investments in stationary storage in the OPEN 2009, OPEN 2012, and SBIR programs

Stationary Energy Storage Portfolio

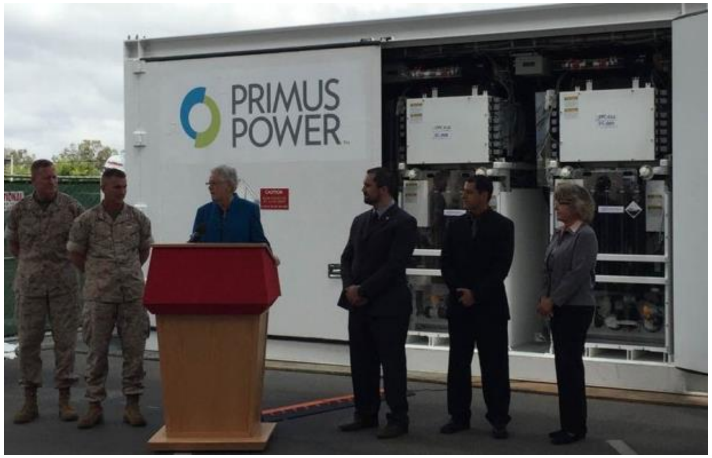


Stationary Storage
- Open FOA 2009: 6
- GRIDS: 12
- SBIR: 5
- Open FOA 2012: 10

ARPA-E stationary storage projects with batteries in customer hands (selected)

FLUIDICENERGY

VIONX ENERGY™



arpa·e CHANGING WHAT'S POSSIBLE

These projects have received significant support from sources other than ARPA-E, including government and private.

CHARGES: Cycling Hardware to Analyze and Ready Gridscale Electricity Storage

1. Economic Valuation
2. Test Protocols
3. Battery Testing
4. Microgrid Testing
5. Commercial Deployment Pathway

UC San Diego

SDGE — A Sempra Energy utility

SOUTHERN CALIFORNIA EDISON

DNV·GL

NIRE Renewable Energy Solutions

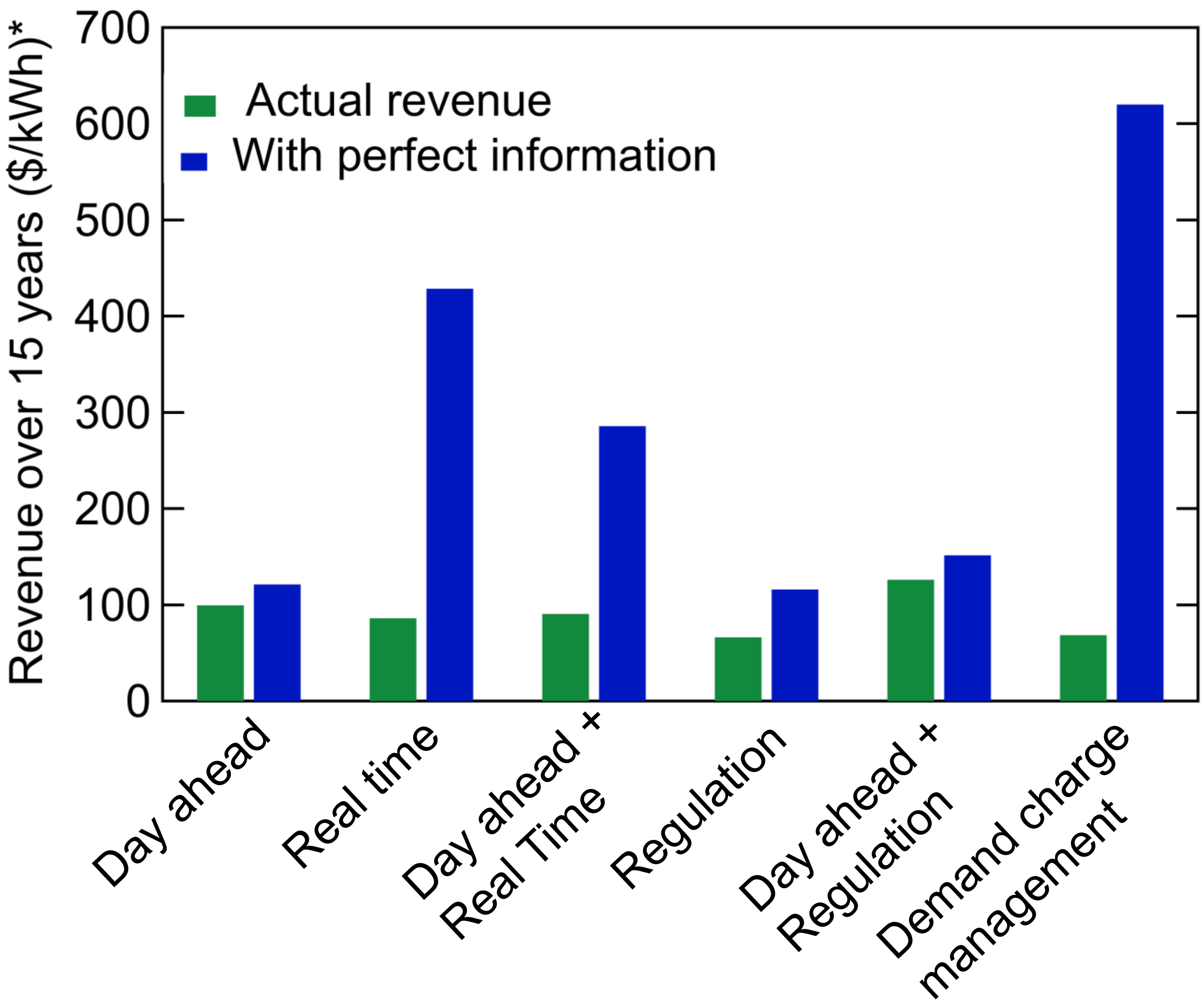
conEdison

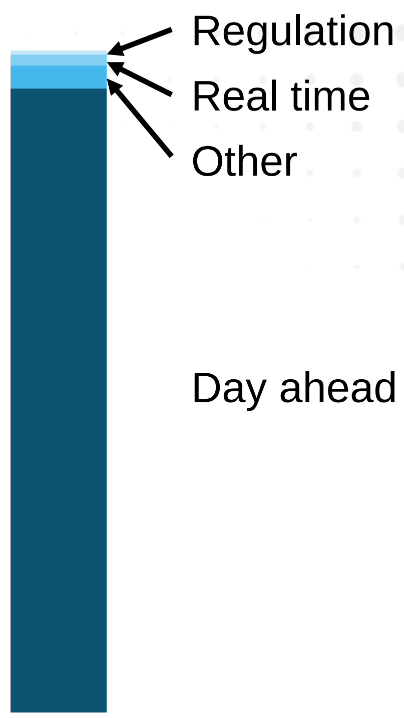
NEXTera ENERGY

Google

NY BES+

Sample UCSD Result: CA Wholesale Market





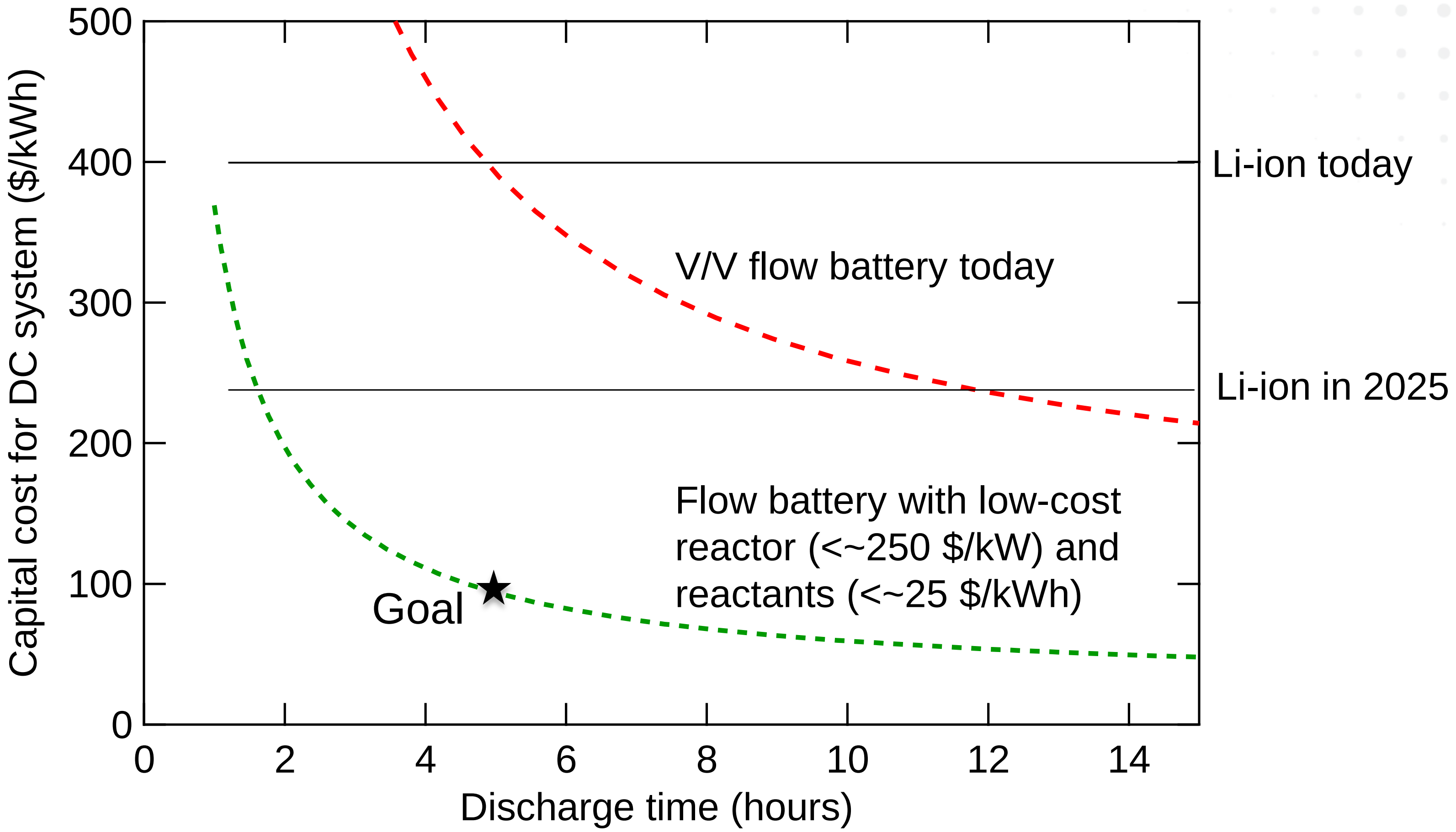
CAISO wholesale energy price breakdown (2015)

Source: UCSD CHARGES project

CHANGING WHAT'S POSSIBLE

*Energy:Power ratio = 1:1. Assumes a simple 10% discount rate. Excludes any tax or other government incentives.

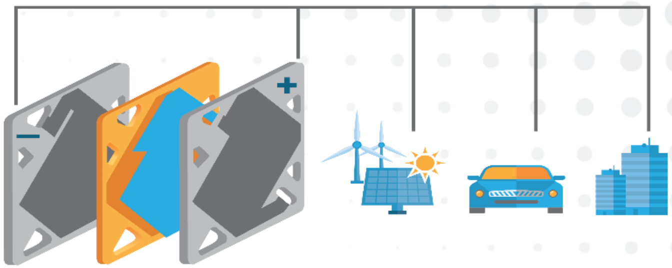
Problem: Li-ion will not reach cost goal for applications that require long-duration storage



Note: capital costs should be seen as approximate.

IONICS

Integration and Optimization of Novel Ion-Conducting Solids



Mission

Create components for electrochemical cells using solid ion conductors to enable transformational performance and cost improvements.

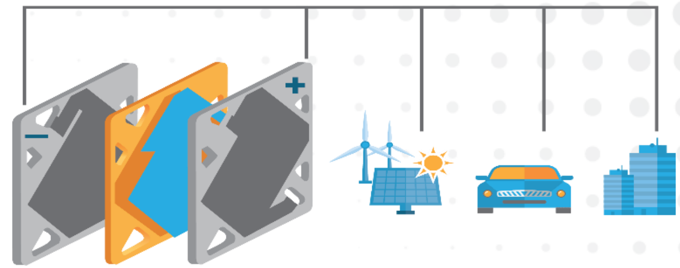
Program Director	Dr. Paul Albertus
Year	2016
Projects	16
Total Investment	$37 Million

Investment areas and impacts

1. Area: Li^+ conductors that enable the cycling of Li metal without shorting.
   Impact: Increase the energy content of Li battery packs by >30%, accelerating adoption of electric vehicles by increasing range and reducing cost.
2. **Area: Selective separators for flow batteries**, expanding the use of novel and low-cost reactants.
   Impact: Develop flow batteries with fully installed costs of 150 $/kWh for a 5h duration, enabling deeper penetration of intermittent renewables.
3. Area: Alkaline conductors with high chemical stability and conductivity.
   Impact: Create alkaline-conducting membranes that open a path to fuel cells and electrolyzers without expensive, rare elements like Pt.

IONICS

16 Project Teams • 3 Technology Areas



1: Li^+ conductors to enable the cycling of Li metal

POLY PLUS

Iowa State University

Oak Ridge National Laboratory

SILA NANOTECHNOLOGIES

PennState

University of Colorado Boulder

24m

ionic MATERIALS

UC San Diego

2: Separators for flow batteries

COLORADO SCHOOL OF MINES

United Technologies Research Center

Washington University in St. Louis

University of Colorado Boulder

3: Alkaline conductors

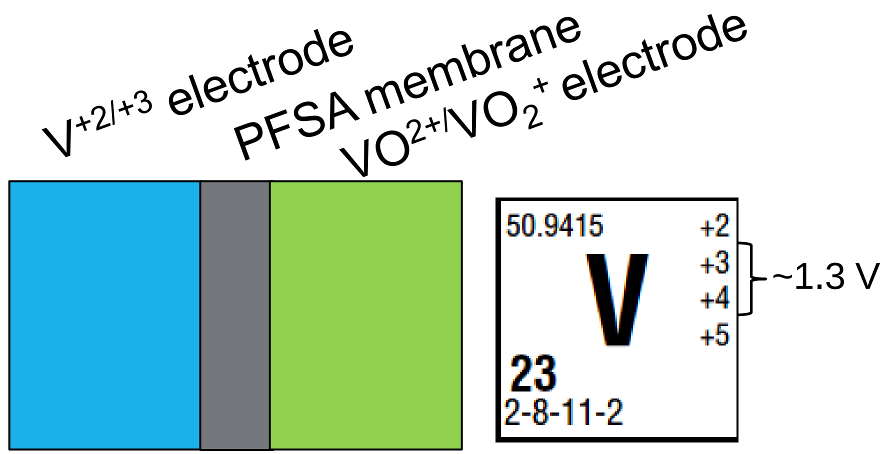
University of Delaware

Rensselaer

3M

Area 2: Cycling liquid reactants

Today's V/V flow battery

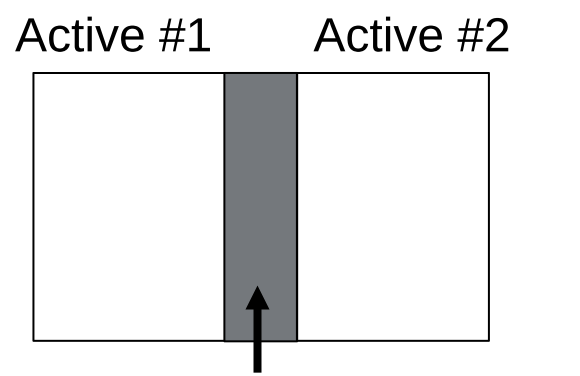


V crossover of ~2% / cycle is *reversible*

IONICS goal: Eliminate crossover, decouple electrodes, enable low-cost reactants

Challenge: Vanadium cost

Active material	Cost ($/kWh)
Vanadium	50 to 100 $/kWh
Iron	~15 $/kWh
Zn/Br_2	~15 $/kWh
Organics, organometallics*	<25 $/kWh



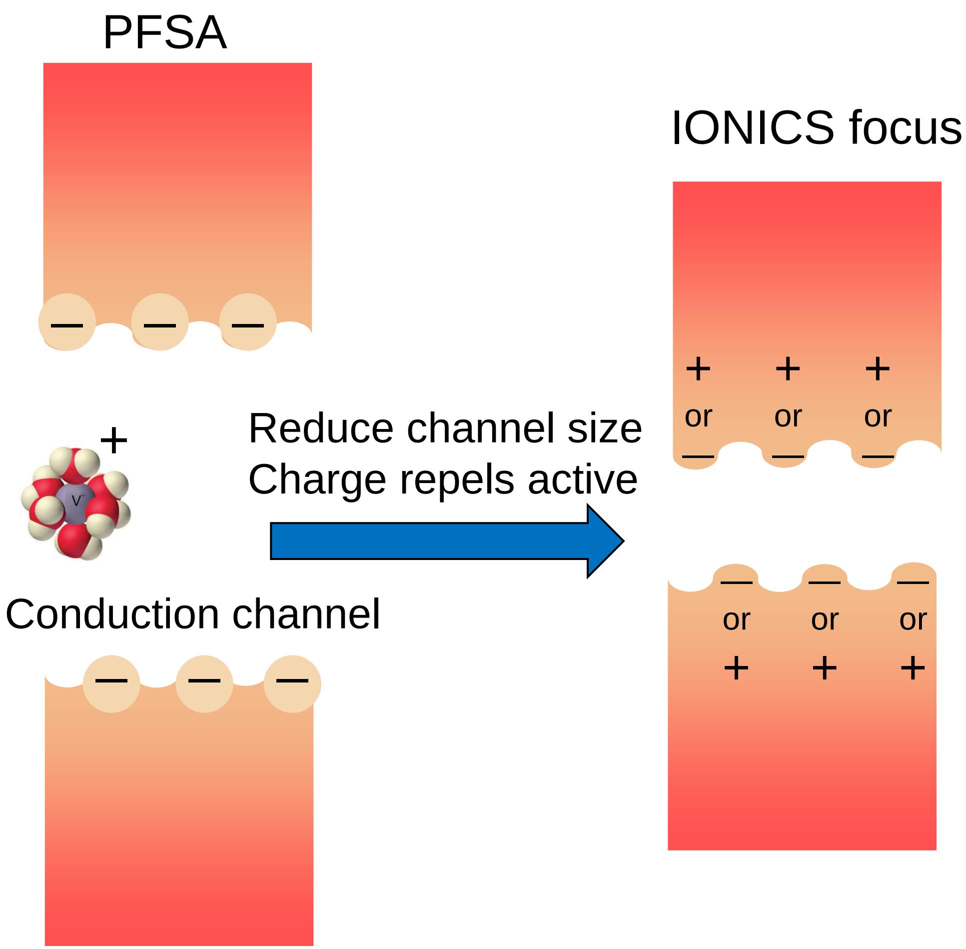
Membrane with 99.995% selectivity allows 5,000 cycles

arpa·e CHANGING WHAT'S POSSIBLE

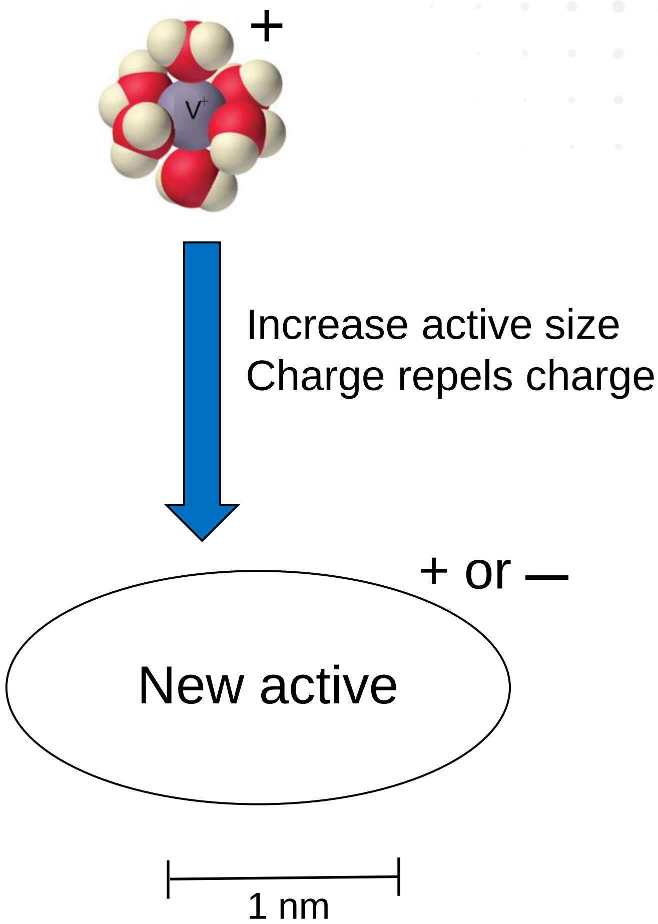
* Achieving cost target requires careful choice of molecule and synthetic route.

IONICS approaches to selective membranes

IONICS: Membrane design

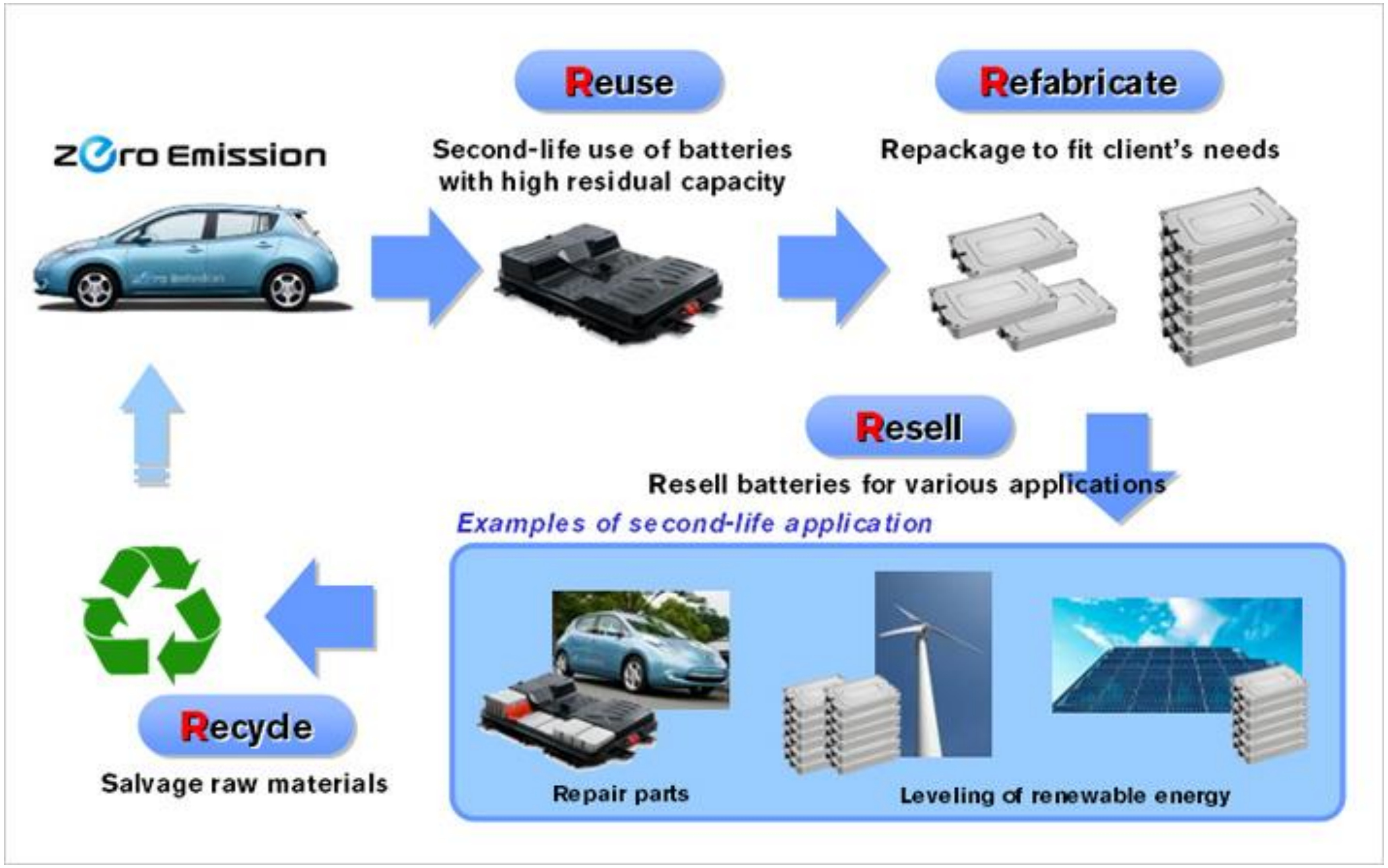


IONICS : Active species design



What's next (maybe)? Redesign, reuse, recycling, rejuvenation of automotive batteries

- OEMs are actively thinking through the entire life of vehicle batteries; can advanced technology play a role?



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