3RD ANNUAL ENERGY STORAGE GRAND CHALLENGE SUMMIT

DOE's Fundamental Science Underpinning Energy Storage

ENERGY STORAGE GRAND CHALLENGE
U.S. DEPARTMENT OF ENERGY

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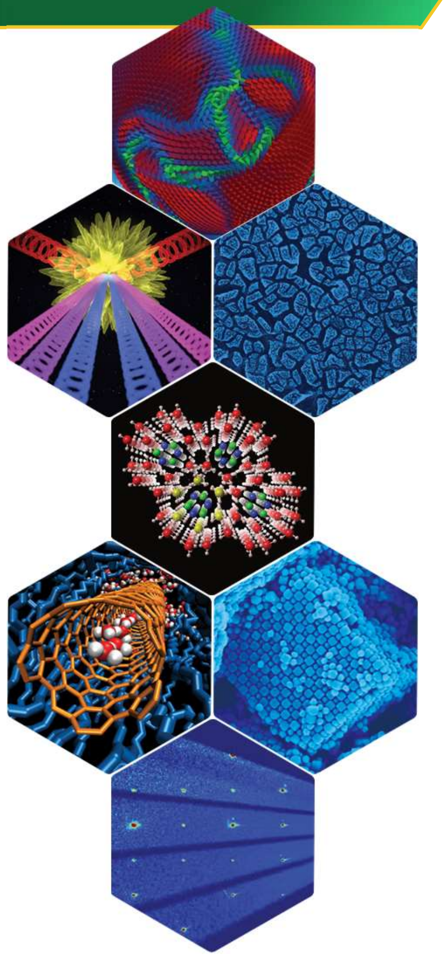
Basic Energy Sciences Mission

To understand, predict, and ultimately control matter and energy at the electronic, atomic, and molecular levels



BES fulfills its mission through:

- Supporting basic research to discover new materials and design new chemical processes that underpin a broad range of energy technologies
  - **Critical role in clean energy research**
- Operating **world-class** scientific user facilities in x-ray, neutron, and electron beam scattering as well as in nanoscale research
- Managing construction and upgrade projects to maintain **world-leading** scientific user facilities

Fundamental Research for Energy is Supported in Each of the Major BES Research Modalities

Increasing scope and size

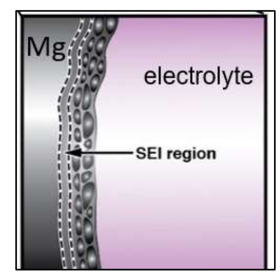
- ## Core Research
  Single investigators (~$150K/year) and small groups ($500K-$2M/year) engage in fundamental research related to any of the BES core research activities. Investigators propose topics from the annual SC FOA, through their national lab, or through special topic FOAs; typically, 3-year awards. Annual SC FOA open year-round. Includes SC Early Career Research Program.

- ## Energy Frontier and Energy Earthshot Research Centers
  $2-4 million/year research centers for 4-year award terms; focus on fundamental research described in Basic Research Needs Workshop reports.

- ## Energy Storage & Fuels from Sunlight Energy Innovation Hubs
  Large-team research awards (5-year terms;$8-25M/year) focus on topics that have proven challenging for traditional funding modalities and for which success could be transformative to science and technology. Project goals, milestones, and management structure are a significant part of the proposed Hub plan.

Lithium Diffusion

Polymer Electrolytes



New Battery Chemistries

Overcoming S&T Challenges to Meet Transformative Energy Goals

DOE's Energy Earthshots™ target the remaining, major RD&D breakthroughs we know we must achieve in the next decade to solve the climate crisis and reach our 2050 net-zero carbon goals.

Hydrogen Shot

1 Dollar | 1 Kilogram | 1 Decade

Long Duration Storage Shot

Reduce storage costs by 90%*… …in storage systems That deliver 10+ hours of duration …in 1 decade

*from a 2020 Li-Ion baseline

Carbon Negative Shot

<100 Dollars | 1 Ton | 1 Decade

Clean Fuels and Products

85% Reduction | 2035

Enhanced Geothermal Shot

90% Reduction | 2035

Floating Offshore Wind Shot

>70% Reduction | 2035

Industrial Heat Shot

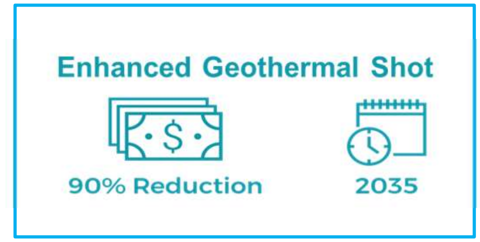
85% Reduction | 2035

https://www.energy.gov/policy/energy-earthshots-initiative

SC Energy Earthshots Initiative

Apr. 2023

- Addresses key research challenges at the interface between basic research and applied R&D to realize DOE Energy Earthshots stretch goals.
- BES, ASCR, and BER issued an FY 2023 lab announcement for Energy Earthshot Research Centers (EERCs).
  - Modeled on EFRCs, EERCs will support large multi-investigator, multi-disciplinary, and multi-institution (academic, national laboratory, industrial) teams to advance foundational knowledge and enabling capabilities in experimental & computational chemical/materials sciences to address Earthshot goals.
  - Closely coordinated with the Energy Technology Offices and existing research consortia/demonstration projects, to establish teams that span the R&D continuum and accelerate both science and technologies—providing a strong bridge between BES and technology research.
- EERCs are complemented with foundational science, small group awards.
  - Focus on use-inspired fundamental research to address knowledge gaps that limit achievement of the Energy Earthshot goals.



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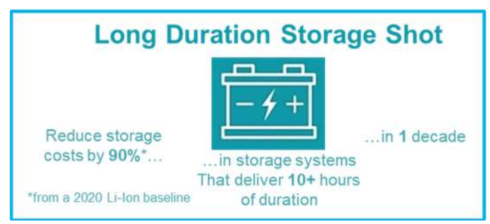
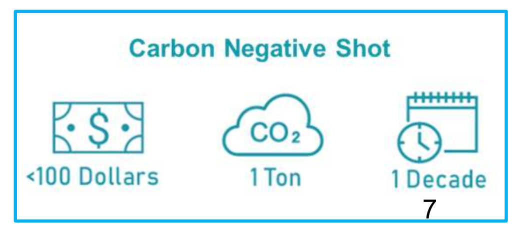


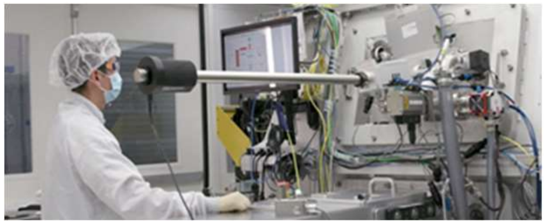


FY 2024 Request: SC Energy Earthshots Initiative

Joint initiative between BES, ASCR, and BER to addresses key research challenges at the interface between basic research and applied R&D to realize DOE Energy Earthshots stretch goals. (+$35M; +$75M for all of SC):

Two complementary programs:

- Energy Earthshot Research Centers (EERCs): Multi-disciplinary, multi-institutional teams led by DOE laboratories focused on key research challenges at the interface of basic and applied R&D.
- Scientific Foundations for Energy Earthshots: Small group awards led by academic or private sector institutions focused on use-inspired foundational science addressing knowledge gaps limiting achievement of Earthshot goals.



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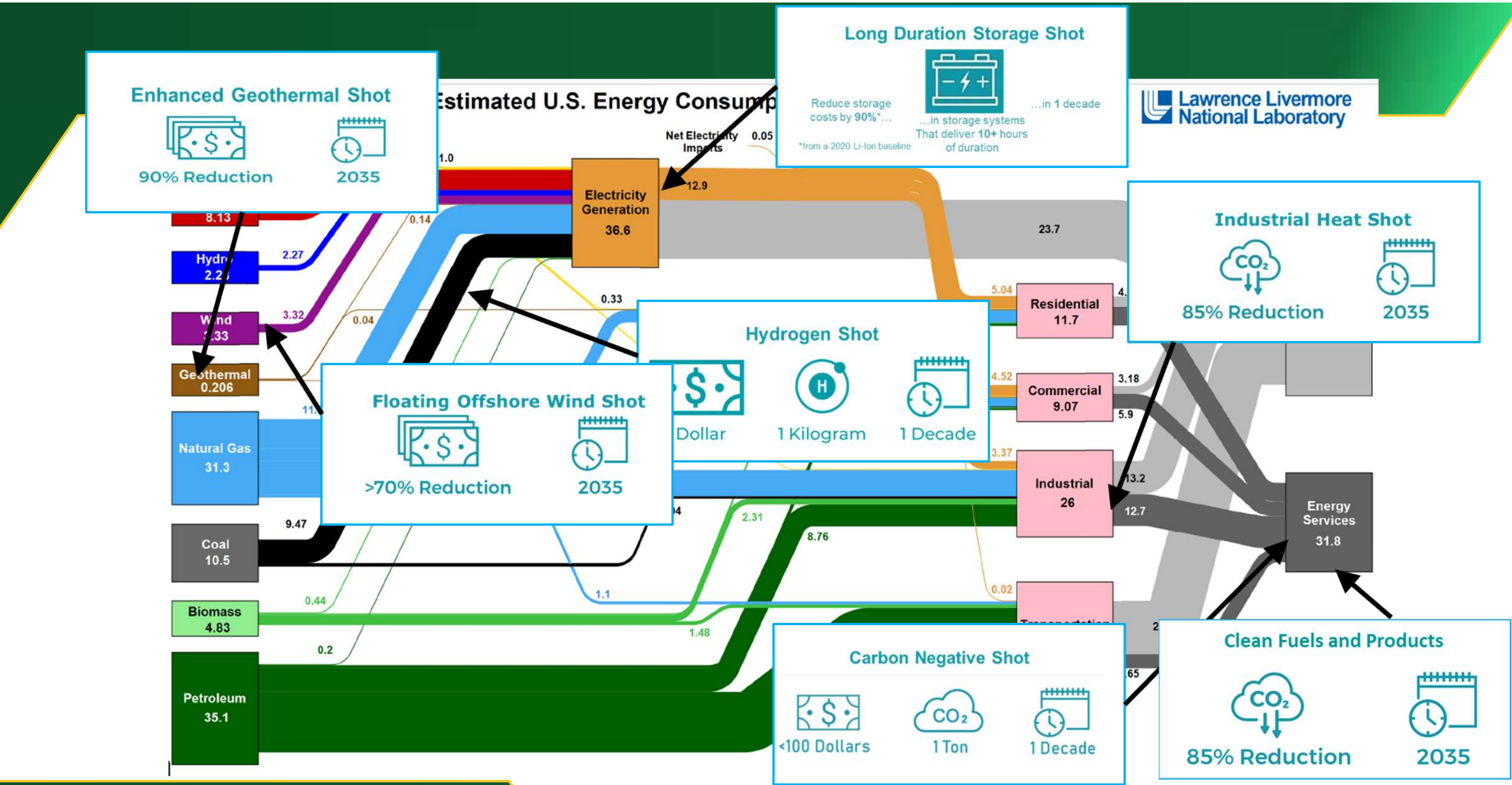
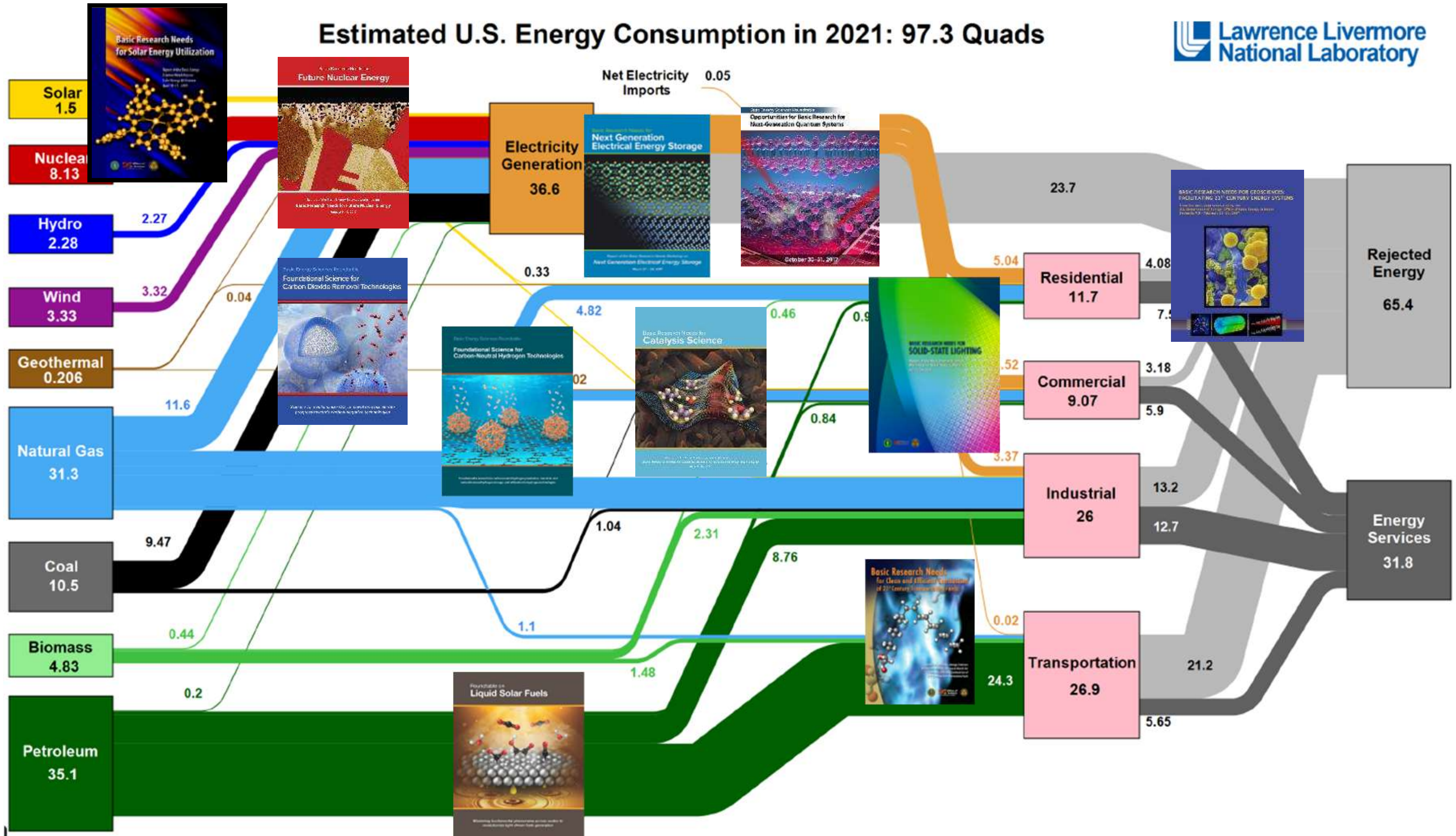
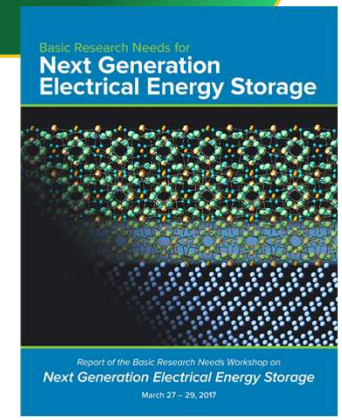

Estimated U.S. Energy Consump
Lawrence Livermore National Laboratory
Enhanced Geothermal Shot
90% Reduction
2035
Long Duration Storage Shot
Reduce storage costs by 90%*…
…in storage systems That deliver 10+ hours of duration
…in 1 decade
*from a 2020 Li-Ion baseline
Industrial Heat Shot
85% Reduction
2035
Hydrogen Shot
Dollar
1 Kilogram
1 Decade
Floating Offshore Wind Shot
>70% Reduction
2035
Carbon Negative Shot
<100 Dollars
1 Ton
1 Decade
Clean Fuels and Products
85% Reduction
2035
Net Electricity Imports
0.05
Electricity Generation
36.6
12.9
23.7
Hydro
2.27
Wind
3.32
Geothermal
0.206
Natural Gas
31.3
Coal
10.5
9.47
Biomass
4.83
0.44
1.48
Petroleum
35.1
0.2
8.13
0.14
0.04
0.33
1.1
2.31
8.76
0.02
5.04
Residential
11.7
4.52
Commercial
9.07
3.18
5.9
3.37
Industrial
26
13.2
12.7
Energy Services
31.8

Basic Research Needs Reports Address Many Energy Topics



Basic Research Needs Workshop on Next-Generation Electrical Energy Storage



Tune functionality of materials and chemistries to enable holistic design for energy storage

How can we understand the functionality of materials sufficiently to anticipate their behavior in electrochemical configurations? How can these insights inform the design of chemistries, materials, and structures for future energy storage?

Link complex electronic, electrochemical, and physical phenomena across time and space

What modeling frameworks can express the spatiotemporal evolution of material-chemical systems across varying spatial and temporal scales?
How can models inform experimental strategies to provide insight on electrochemical phenomena?

Control and exploit the complex interphase region formed at dynamic interfaces

Can we characterize the chemical and material reactions and behaviors that comprise dynamic interfaces? How can interfaces be designed and synthesized to enhance storage performance and/or mitigate degradation?

Revolutionize energy storage performance through innovative assemblies of matter

What strategies can we use to exploit high-capacity electrode materials and higher voltage electrolyte chemistries while ensuring reliable cycling? What approaches are needed to perform design, characterization, and simulation at the mesoscale?

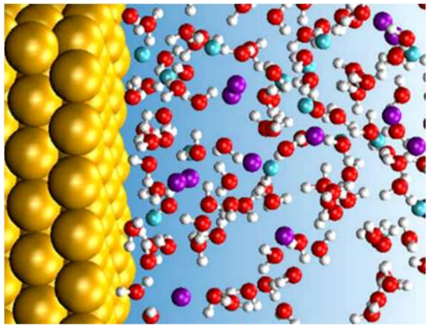
Promote self-healing and eliminate detrimental chemistries to extend lifetime and improve safety

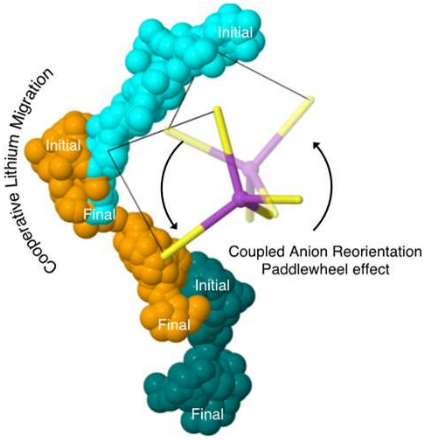
What drives the key degradation and failure mechanisms? How can these, and possible mitigation strategies, be revealed through modeling and characterization of representative and model systems?

https://science.osti.gov/-/media/bes/pdf/reports/2017/BRN_NGEES_rpt.pdf

BES Support for Energy Storage Research

- Fundamental research underpinning electrical energy storage - anodes, cathodes, electrolytes, interfaces, flow batteries and membranes, as well as data and software in the Materials Project.
- The Batteries and Energy Storage Hub Program focuses on science for next-generation batteries for transportation and grid storage; activities are explicitly tailored to link science and technology communities.
  - Joint Center for Energy Storage Research (JCESR), 2012-2023
  - FY2023 Re-competition underway (2-3 awards anticipated)
- Six Energy Frontier Research Centers are focused on basic research directly linked to understanding and advancing energy storage concepts.
- >40 university grants and national labs field work proposals support a wide range of basic science related to energy storage, including use of advanced characterization and computing at Office of Science user facilities.



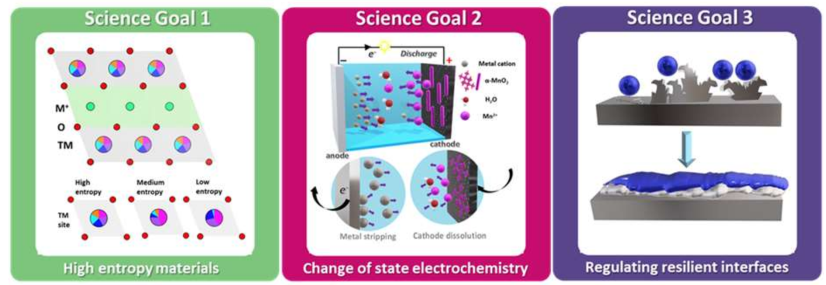


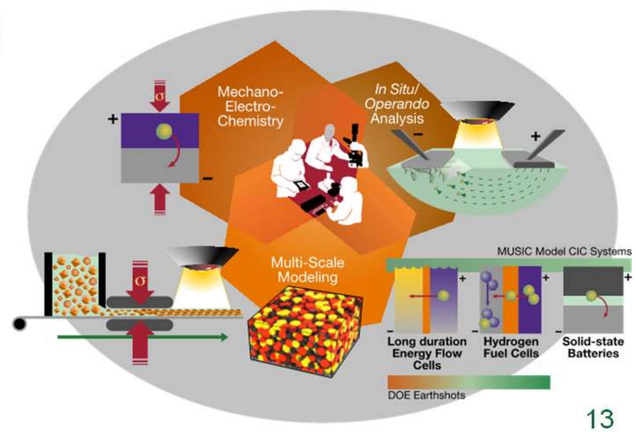
Energy Frontier Research Centers (EFRCs)

- Coupling "basic research needs" for energy applications and "grand-challenge science"
- Bringing the academic community together with the national labs and industry to enable high-impact collaborative science with relevance to energy science

Currently 6 EFRCs performing research underpinning energy storage:

- Center for Mesoscale Transport Properties
  Esther Takeuchi (Stony Brook University)
- Mechano-Chemical Understanding of Solid Ion Conductors
  Jeff Sakamoto (University of Michigan)
- Center for Alkaline-Based Energy Solutions
  Hector Abruña (Cornell University)
- Fast and Cooperative Ion Transport in Polymer-Based Electrolytes
  Valentino Cooper (Oak Ridge National Laboratory)
- Breakthrough Electrolytes for Energy Storage and Systems
  Robert Savinell (Case Western University)
- Center for Synthetic Control Across Length-scales for Advancing Rechargeables
  Sarah Tolbert (UCLA)





JCESR (2012-2023):
Bottom-Up Battery Design

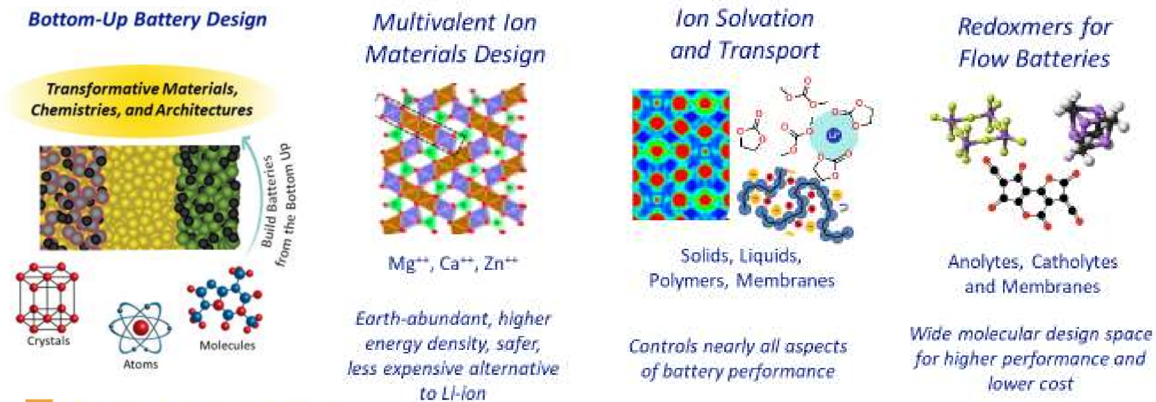
Build batteries from the bottom up
Atomic and molecular battery design

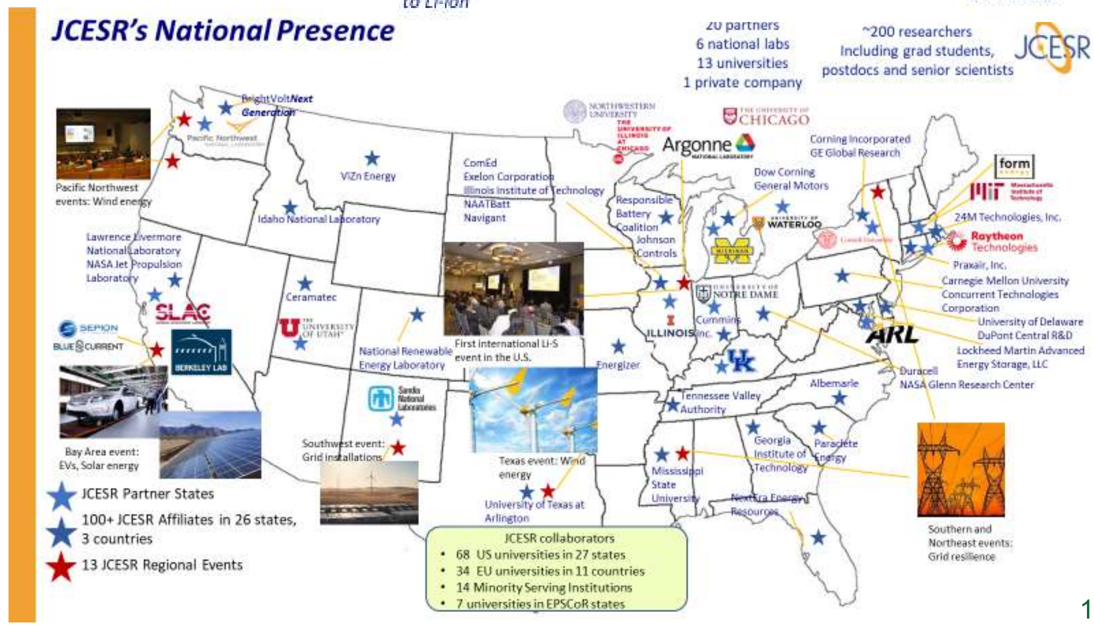
Extensive use of simulation and machine learning
Materials discovery
Atomic/molecular level understanding

Multi-modal experiment + simulation
Broad range of experiments and simulations per project/paper

Techno-economic models inform strategic choices
System performance and cost
Materials performance targets

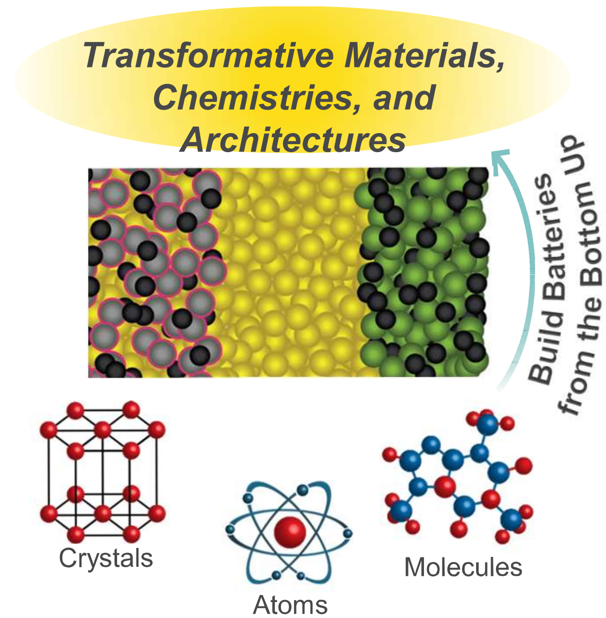
Industrial and community engagement
Communicating and collaborating beyond JCESR





JCESR Joint Center for Energy Storage Research

Joint Center for Energy Storage Research (JCESR)



Venkat Srinivasan
Argonne National Lab

- Context for JCESR
- Vision, goals
- Enduring legacies
- Science challenges in storage

ESGC Summit
July 25, 2023

U.S. DEPARTMENT OF ENERGY

JCESR Joint Center for Energy Storage Research

THE ENERGY STORAGE LANDSCAPE IN 2012

Li-ion: one-size-fits-all battery
for many applications

Electric Vehicles and Electricity Grid

Promising opportunities, many commercial barriers

Electric Vehicles

High cost, low range, no charging infrastructure, tiny market

Electricity Grid

High cost: Battery $825/kWh

Battery storage: short lifetime, no deployment at scale

JCESR Vision

Fundamental science to enable beyond Li-ion batteries that can meet transportation and grid targets

Government

Argonne wins Manhattan Project for car batteries

By Paul Merrion

November 29, 2012 06:00 AM

Argonne National Laboratory has won federal funding for a highly coveted research center modeled after Bell Labs and the Manhattan Project that will aim to create smaller, cheaper batteries for electric vehicles and other long-range energy needs. The Energy Department's decision is expected to be announced later this week, according to two Capitol Hill sources. Argonne's Joint Center for Energy Storage Research proposal, which includes a team of four other national labs, four universities and private industry, was supported by 10 senators and 39

GEORGE CRABTREE: THE FOUNDING DIRECTOR OF JCESR

Congressional Record

United States of America

PROCEEDINGS AND DEBATES OF THE 118th CONGRESS, FIRST SESSION

House of Representatives

Celebrating the Life of Mr. George Crabtree

HON. BILL FOSTER
OF ILLINOIS
IN THE HOUSE OF REPRESENTATIVES
April 28, 2023

Mr. FOSTER. Mr. Speaker, I rise today to honor Mr. George Crabtree, an energy trailblazer and fellow scientist whose nearly six-decade career at Argonne National Laboratory advanced a number of scientific disciplines and inspired colleagues and friends, here and around the world.

Born and raised in Little Rock, Arkansas, George eventually moved to Illinois where he graduated from Proviso West High School. He ultimately joined Argonne National Laboratory as a lab technician in 1964 and received his Ph.D.

George was widely recognized and admired as a brilliant materials scientist and champion of superconducting materials and better batteries. As director of the U.S. Department of Energy's Joint Center for Energy Storage Research, George bolstered the national agenda to tackle the climate crisis and build a clean and equitable energy economy. He helped pioneer early research into high-temperature superconductors and in them, he discovered new phases of superconducting vortex matter. George's research on superconductors gained him recognition as a member of the American Association for the Advancement of Science, the American Physical Society, and the National Academy of Sciences.

In addition to his work at Argonne, George was a professor of physics at Northern Illinois University for 13 years and a Professor of Physics at the University of Illinois at Chicago for 12 years. George was a luminary in every sense of the word, and his work and dedication to the global scientific community will not be forgotten. Join me as I celebrate the life and legacy of Mr. George Crabtree.

U.S. HOUSE OF REPRESENTATIVES

Bill Foster

Home > MRS Bulletin > Article

Society News | Published: 03 April 2023

In remembrance: George Crabtree (1944–2023)

Gentleman–scientist at the forefront of sustainable energy

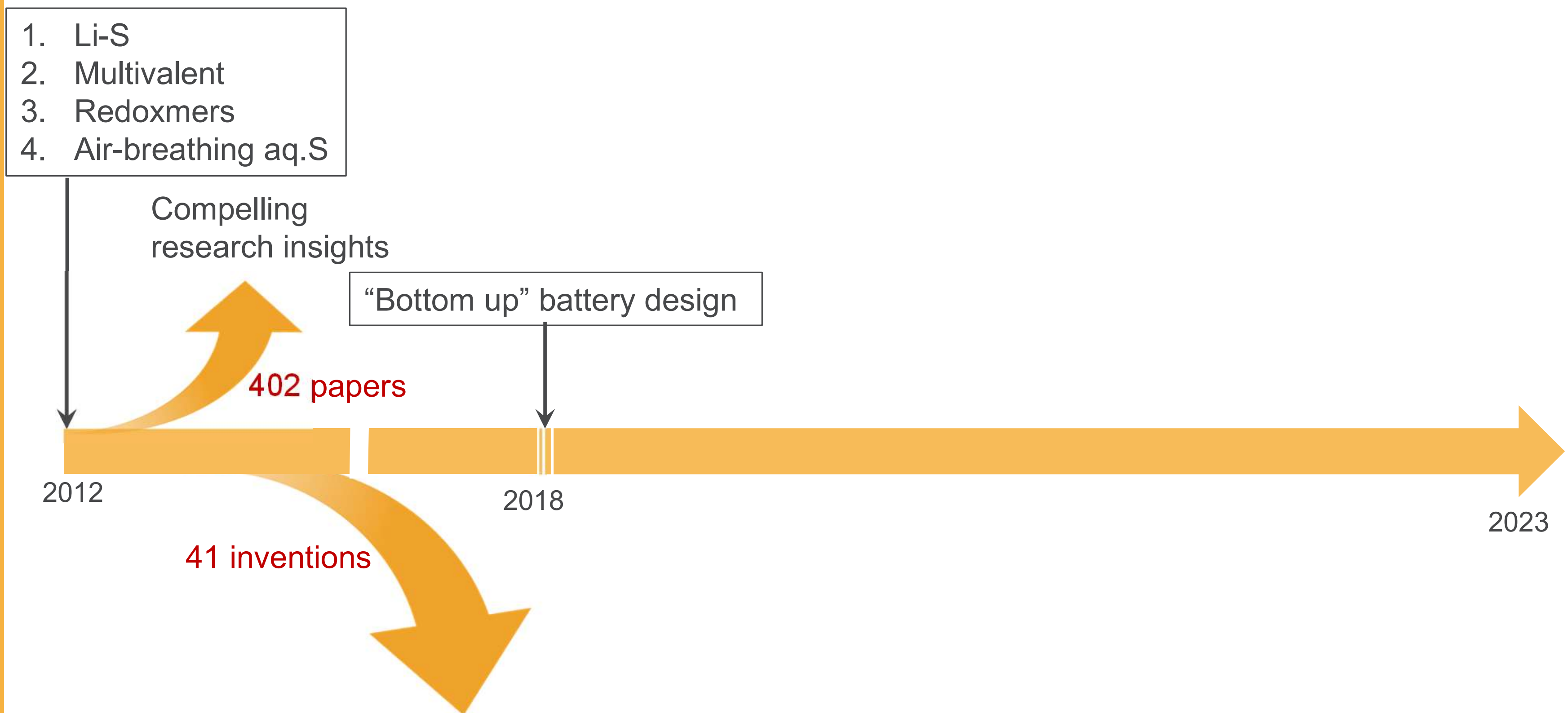
Elizabeth Kócs, David Cahen & Dave Ginley

MRS Bulletin **48**, 426–427 (2023) | Cite this article

Scientist, visionary, and gentleman

A stunning loss to the scientific community and to humanity, the news of George Crabtree's recent demise came as a shock to his numerous colleagues and friends. George was the epitome of an inspirational visionary and an astounding human being, as well as a force for critical and interdisciplinary scientific thought. Remembered by all as approachable, warm,

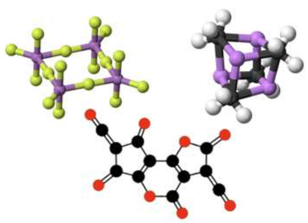
EVOLUTION OF JCESR



JCESR RENEWAL VISION AND GOALS

Three Primary Goals

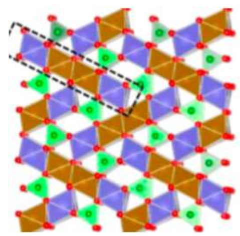
Redoxmers for Flow Batteries



Anolytes, Catholytes and Membranes

Wide molecular design space for higher performance and lower cost

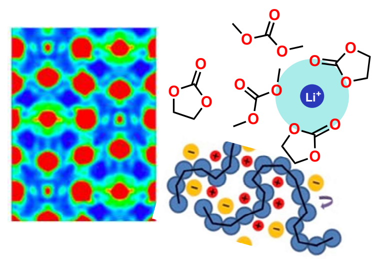
Multivalent Ion Materials Design



Mg^{++}, Ca^{++}, Zn^{++}

Material diversification to ensure supply chain security

Ion Solvation and Transport

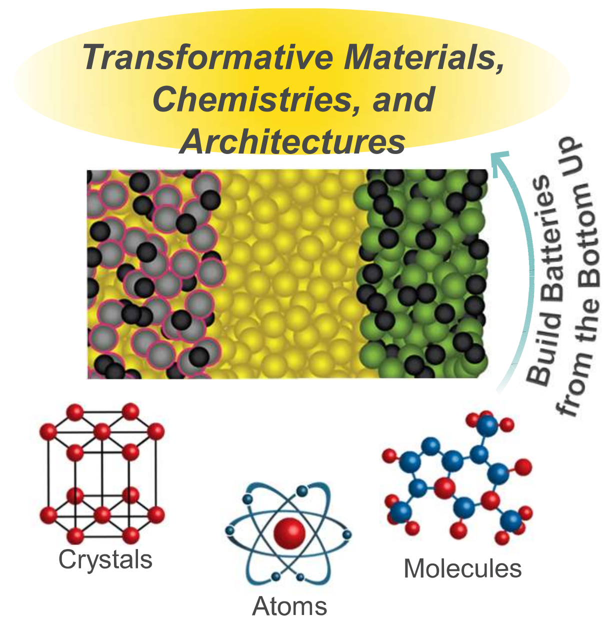


Solids, Liquids, Polymers, Membranes

Controls nearly all aspects of battery performance

Vision

Bottom-Up Battery Design



JCESR Overview in one paper
Trahey et al, Energy Storage Emerging: A Perspective from JCESR, PNAS 117, 12550 (2020)

Highly Cited ISI Web of Science

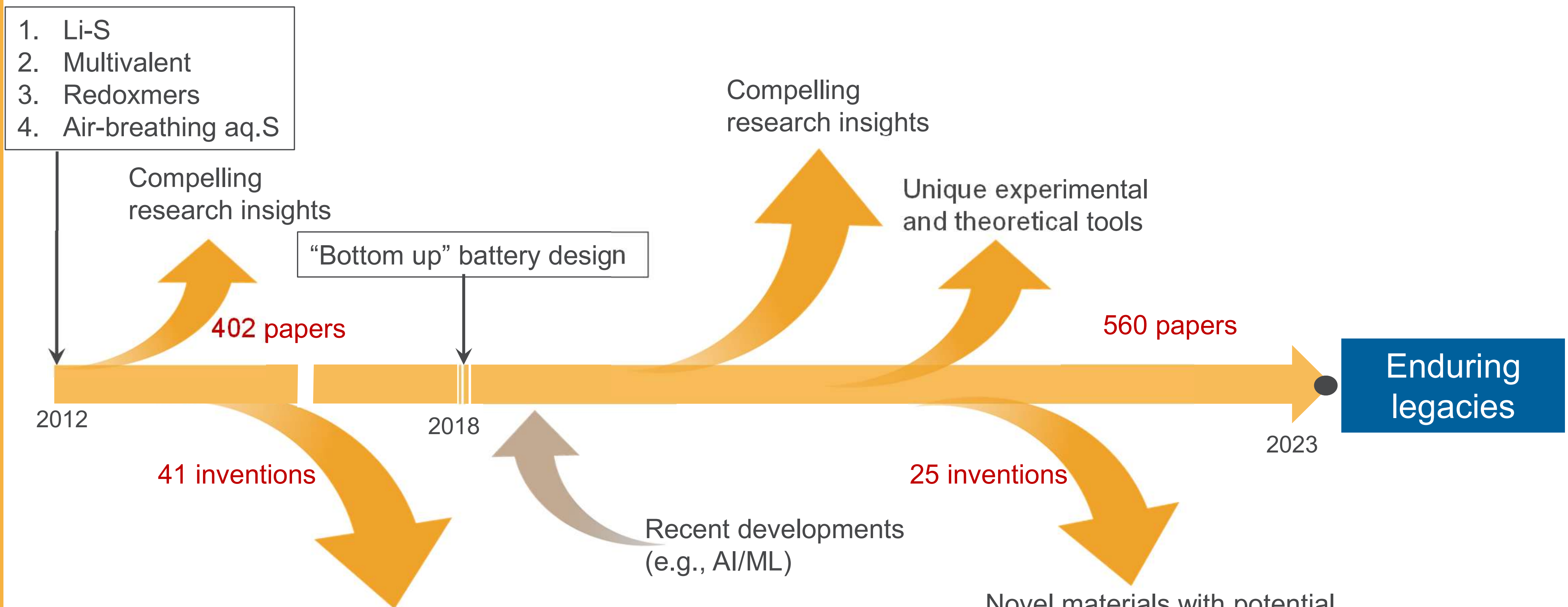
U.S. DEPARTMENT OF ENERGY

JCESR | JOINT CENTER FOR ENERGY STORAGE RESEARCH

THE TEAM

20 partners
- 6 national labs
- 13 universities
- 1 private company

EVOLUTION OF JCESR



form energy

BLUE CURRENT

SEPION TECHNOLOGIES

JCESR ENDURING LEGACIES

Scientific

- Ion solvation and its impact on batteries
- Divalent working ions as an enabler
- Redox active molecules (redoxmers) for storage
- Date Science, machine learning, and automated labs
- in situ, Operando characterization

Technological

- New materials w/ technological impact
- Patents
- Spin offs
- Follow-on funding

Operational

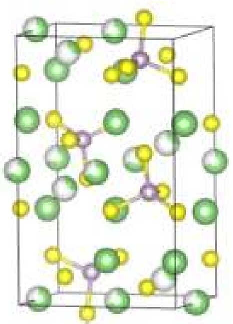
- Technoeconomic to guide science
- Managing team science
- Training the future workforce

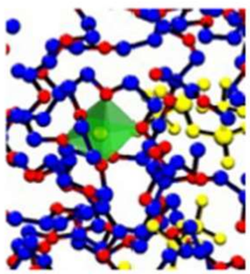
JCESR EXTENDED THE CONCEPT OF SOLVATION FROM LIQUID ELECTROLYTES TO INORGANIC SOLIDS AND POLYMERS

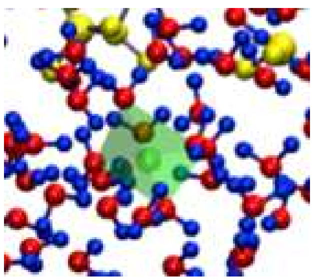
Developed a common framework across phases as a guide to describe and improve ion transport

- Before JCESR, the term solvation was generally used to describe solvation shells in liquid electrolytes.
- New principles that govern the cooperative motion of ions and molecules within and outside the solvation structure (shells or cages) in all three classes of electrolytes were established.
- Discovered that theories developed first for concentrated electrolytes also apply to solid electrodes where the mobile species are ions and the electrons.

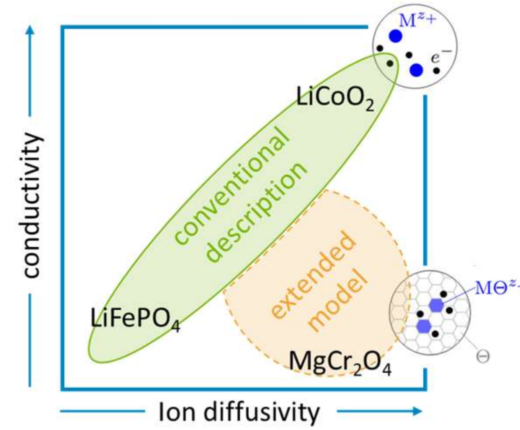
Electrolytes
Solids, Polymers, Liquids







Solid Electrodes
Electron – ion correlations



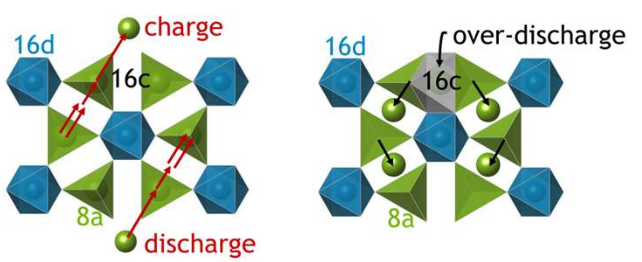
DOI: 10.1016/j.trechm.2021.06.004
DOI:10.1021/jacs.2c03491

JCESR ADVANCED THE DESIGN PRINCIPLES NECESSARY TO TRANSITION FROM MONO TO DIVALENT ENERGY STORAGE MATERIALS

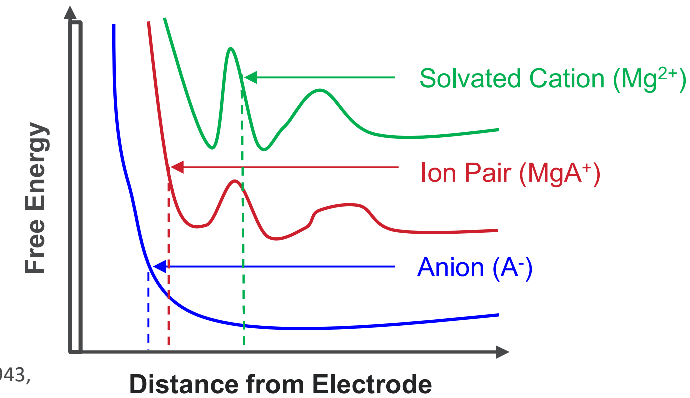
Advanced divalent energy storage science by shifting focus to concerted cation motion in the solid state and cation coordination dynamics in the interfacial liquid state.

- Predictive solid-state design is advanced from conventional site-specific activation barriers to concerted charge motion through structural cation rearrangement,[1] cluster anion reorientation,[2] and coupled electron–ion transport.[3]
- Predictive liquid electrolyte design is advanced from conventional isolated constituent stability to controlling solvation structure at the electrode interface through coordination reconfiguration,[4] interfacial restructuring,[5] and ligand stabilization.[6]

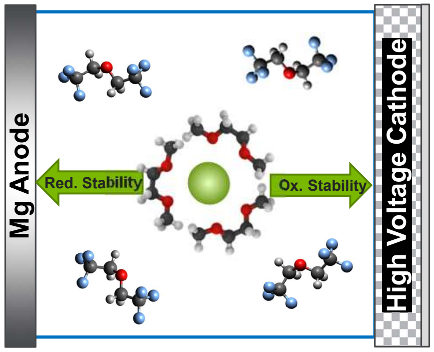
Structural cation rearrangement
Pushing M^{2+} reversibility limits



Interfacial restructuring
Controlling species approach



Coordination reconfiguration
Stabilizing via selective solvation



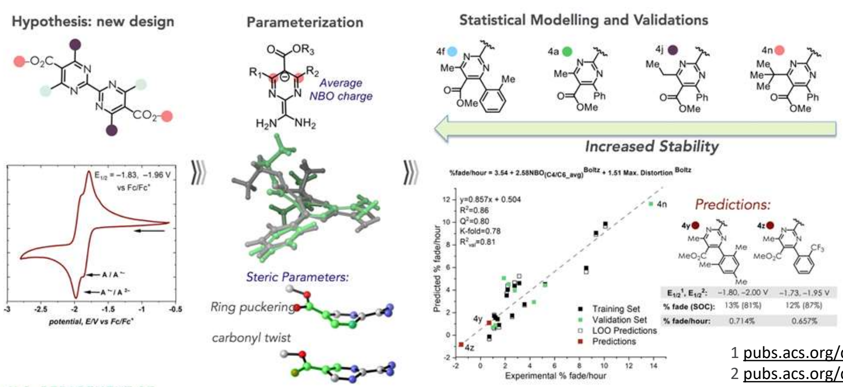
[1]Lapidus DOI 10.1021/jacs.1c04098,
[2]Tsai DOI 10.1002/aenm.202203284,
[3]Johnson & Mistry DOI 10.1021/jacs.2c03491,
[4]Hahn DOI 10.1039/d0ta02502j,
[5]Prendergast DOI 10.1021/acs.jpclett.1c00943,
[6]Persson DOI 10.1021/acs.jpcc.2c06653.

JCESR IDENTIFIED REDOXMERS WITH EXCEPTIONAL PROPERTIES USING AN INTERDISCIPLINARY WORKFLOW

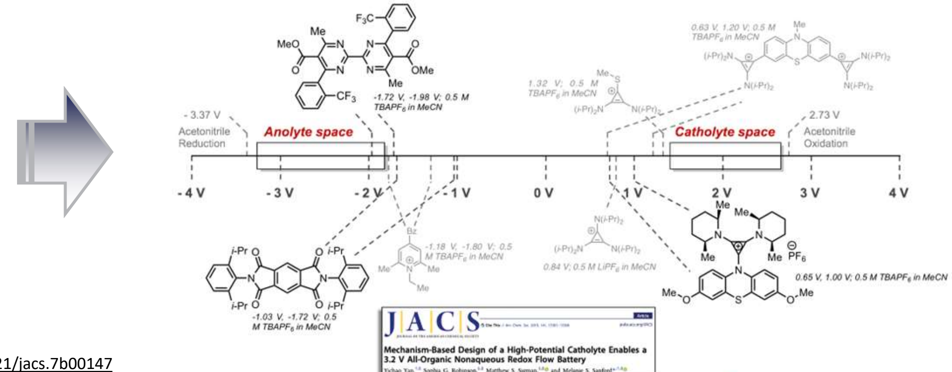
Prompted by chemical experience but perfected through synergistic experiment and computation, we downselected from millions of possibilities to few exceptional redoxmers, ultimately leading to high-performing non-intuitive designs

- Leveraged **machine learning** to design redoxmer structures displaying optimal stability,[1] solubility, and cross-over by funneling **thousands to millions of enumerated candidates**,[2] to hundreds selected for synthesis, and ultimately to few top performers**, for example enabling a 3.2 V NaRFB through high voltage, high solubility posolytes.[3]**
- Used a **multi-scale, multi-property characterization** toolset bolstered on X-rays, rheology, electrode dynamics, and automated characterization **alongside computational modeling** to forecast complex redoxmer interactions.**[4,5]**

Synthesis- characterization-simulation Workflow w/ data science



Discovery of new posolytes and negolytes



1 pubs.acs.org/doi/10.1021/jacs.7b00147
2 pubs.acs.org/doi/full/10.1021/acs.chemmater.0c00768
3 pubs.acs.org/doi/10.1021/jacs.9b07345
4 www.sciencedirect.com/science/article/pii/S0167732221012575
5 pubs.acs.org/doi/full/10.1021/acsmeasuresciau.2c00054

U.S. DEPARTMENT OF ENERGY

JCESR JOINT CENTER FOR ENERGY STORAGE RESEARCH

JCESR Utilized data-science-enhanced simulation to accelerate pace of design and discovery of Energy Storage Materials

JCESR accelerated discovery of redoxmers, electrode materials, and interfaces by developing new general and transferable ML codes, data-driven models, & autonomous electrochemical experiments.

DOI:10.1021/jz502319n
DOI: 10.1021/jacs.7b00147
DOI: 10.1021/acs.chemmater.0c00768

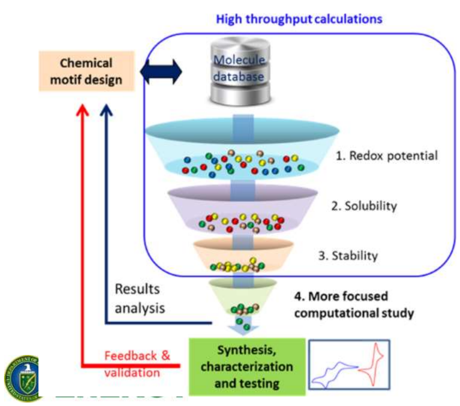
JCESR 1

- **2013**
  - Molecules Materials Simulations
- **2014**
  - Structure-Activity Relationships
- **2016**
  - Electrolyte Genome
  - Electrode Screening

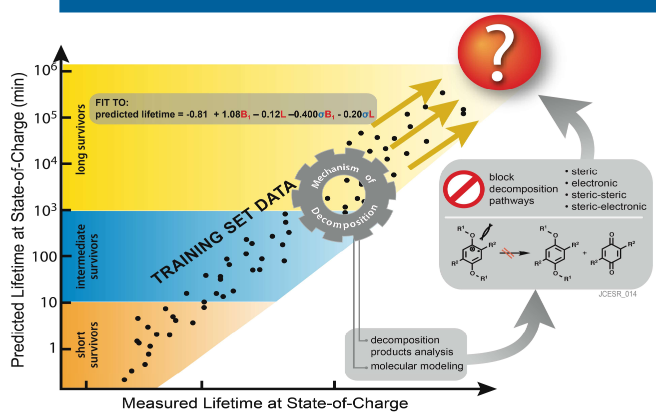
JCESR 2

- **2018**
  - QSAR for redoxmers
- **2019**
  - Data driven models
- **2021**
  - SEI prediction
  - Molecular Optimization
- **2023**
  - Autonomous Discovery

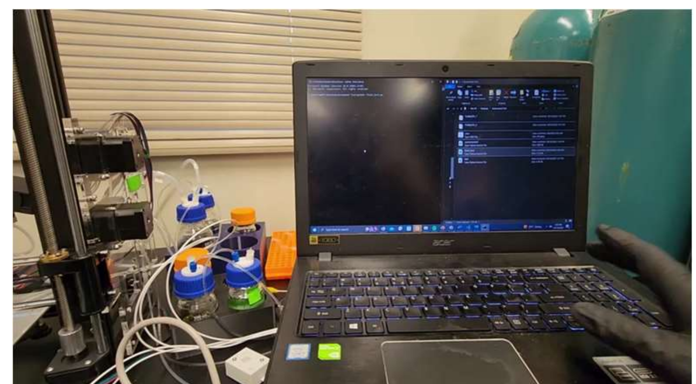
Electrolyte Genome
Database of >20k molecules



Quantitative Structure Activity Relations
Predict new molecules



Electrolab
Automated Echem **lab**

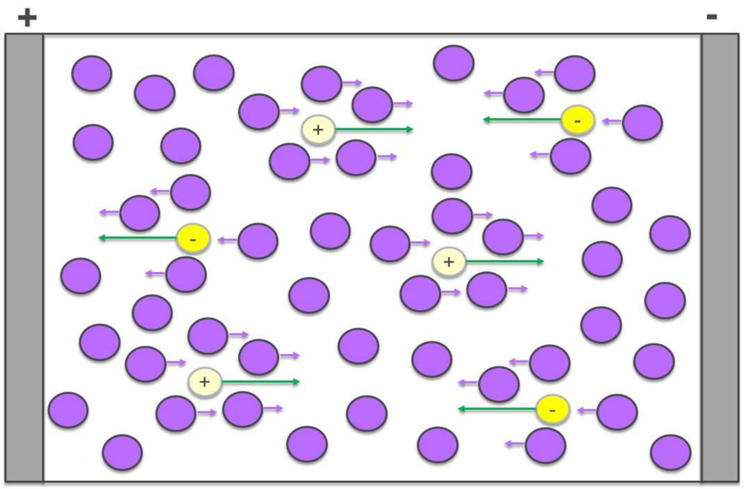


JCESR IDENTIFIED THE CRITICAL ROLE OF NEUTRAL MOLECULES IN ION TRANSPORT

Developed new OPERANDO TOOLS and theoretical models

- Before JCESR, electric-field-induced solvent motion was either ignored or set to zero.
- Developed operando XPCS , the only approach for measuring the velocity of neutral species under electric fields as a function of space and time. This includes solvents and polymers.
- Derived new expressions that relate solvent motion to ion transport and battery performance – they enable new interpretations of species velocities measured by eNMR.
- Showed that fast ion motion of the working ion requires neutral molecules to rapidly get out of their way.

XPCS
measures average velocity of all solvent molecules



eNMR
enables determination of the average velocity of solvent molecules in particular solvation shells & cages

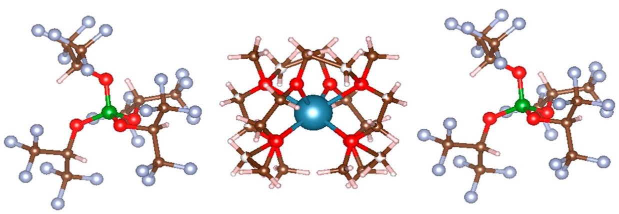
DOI: 10.1039/d0ee02193h
DOI: 10.1149/1945-7111/ ac8246
DOI:10.1103/PhysRevLett.128.198002

JCESR DEVELOPED NEW ELECTROLYTES AND MEMBRANES FOR BEYOND-LITHIUM-ION TECHNOLOGIES

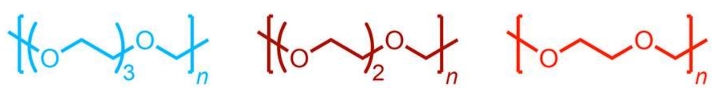
Developed new design and synthesis methods to advance beyond pre-JCESR bottlenecks

- Before JCESR, Ca cells cycled poorly, operated at high temperatures, and had an operating potentials below 2.6 V. The JCESR electrolyte enabled prolonged stable room temperature cycling at 3.2V.
- Optimized ion transport in polyethers, the only class of polymer electrolytes of commercial relevance.
- JCESR developed separators that have increased the capacity retention of non-aqueous redox flow batteries by 2.4 fold during 1000 charge/discharge cycles.

Liquids
Stable electrochem window



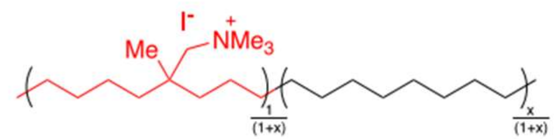
Polymers
Optimized polyethers



P(3EO-MO) $p = 0.57$ | P(2EO-MO) $p = 0.60$ | P(EO-MO) $p = 0.67$

increasing $p = {}^{[O]}/_{[C]}$

Membranes
Eliminated crossover



TMA-PE-x (x = 2-6)

DOI: 10.1021/jacs.1c00941
DOI: 10.1021/acsaem.2c03836
DOI: 10.1021/acsenergylett.2c01551

JCESR PIONEERED THE DEVELOPMENT OF DETAILED TECHNOECONOMIC MODELS FOR BEYOND LI-ION CHEMISTRIES AS A TOOL TO PRIORITIZE RESEARCH

Using technoeconomic principles, we framed the scientific challenge for the community and demonstrated the link between science and application

2012

2014: Flow[1] (677), Li-Air[2] (487)

2015: Li-S[3] (240)

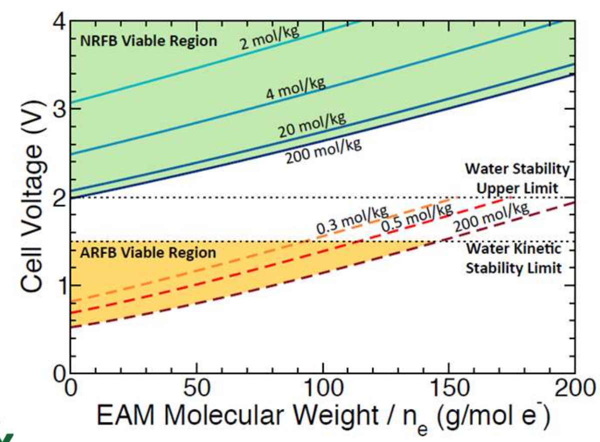
2017: Mg-ion[4] (903), Long duration[5] (162)

2023

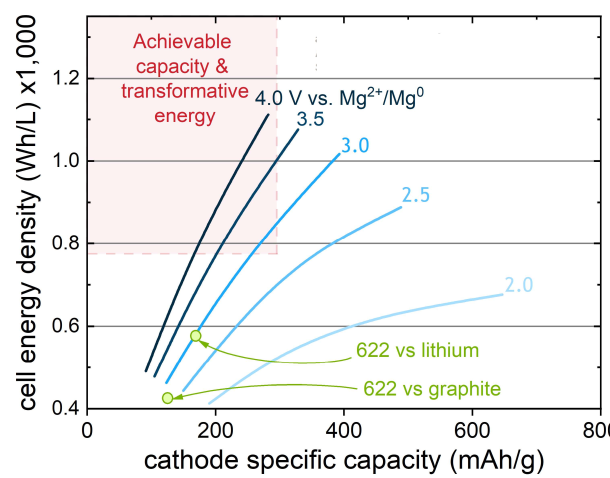
1. 10.1039/C4EE02158D
2. 10.1039/C3EE43870H
3. 10.1149/2.0611506jes
4. 10.1021/acs.chemrev.6b00614
5. 10.1016/j.joule.2017.08.007

Parenthesis denotes citations

Design space for flow batteries
Low cost aqueous and non-aqueous



M^{2+} cathode targets
High voltages > 3.0 V



JCESR INSPIRED THE FORMATION OF THREE SPIN-OFF COMPANIES AND GENERATED 66 INVENTIONS, BOLSTERING US COMMERCIAL LEADERSHIP

Research nucleated in JCESR has resulted in >$900M of follow-on funding, including >$55M from applied offices and industry

Technology Area	Inventions (#)
Redoxmers	22
Lithium-Sulfur	6
Multivalent (Zn/Ca/Mg)	8
Solid-state/Li-metal	7

Notes: Active/available IP only. Other topics with 3 or less active technologies: Membranes, LIB Cathodes, Additives, Supercapacitors, 3D printing.

BLUE CURRENT

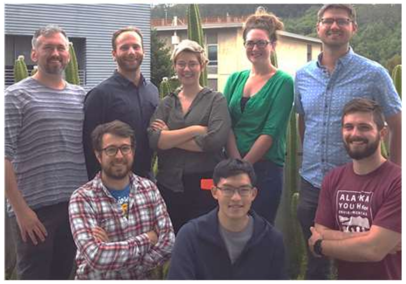
Irune Villaluenga Battery Scientist JCESR Alum

Nitash Balsara Co-founder JCESR Member

Kevin Gao Battery Scientist JCESR Alum

Solid state electrolytes

SEPION TECHNOLOGIES

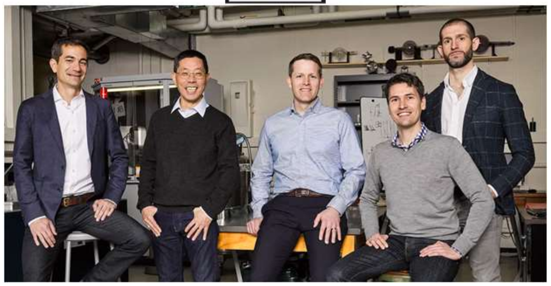


Brett Helms Co-founder JCESR Member

Peter Frischmann Co-founder, CEO JCESR Alum

Microporous polymer membranes

form energy



Liang Su Scientist JCESR Alum

Yet-Ming Chiang Co-founder JCESR Member

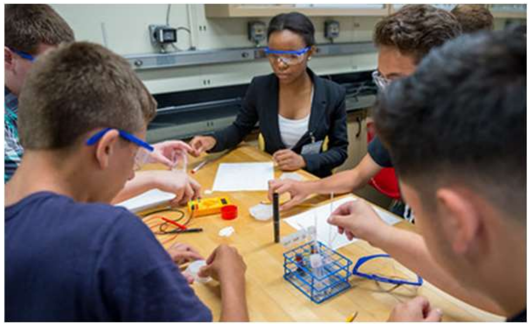
Billy Woodford CTO JCESR Alum

Jarrod Milshtein Senior Manager JCESR Alum

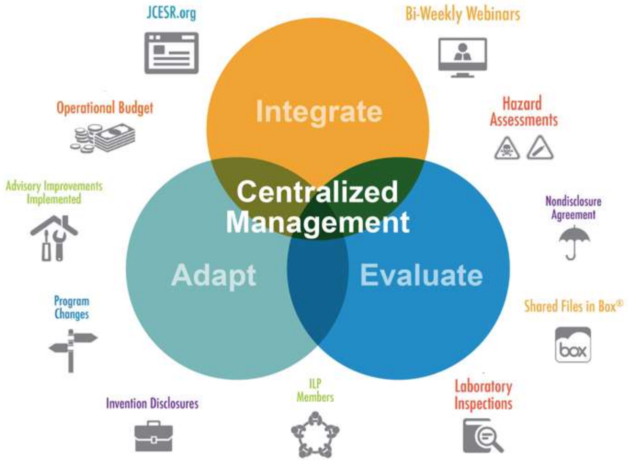
Many-day discharge batteries

JCESR DEVELOPED AND REFINED A SUCCESSFUL MODEL FOR MANAGING TEAM SCIENCE

- JCESR management was recognized with the Secretary of **Energy's Achievement Award for Strategy and Operations in 2018**.
- JCESR developed an **Affiliates Program** and executed **13 Regional Events** (2013-2019) to engage with industrial, academic, utility, and government stakeholders across the US.
- JCESR adapted rolling wave planning and matrixed organization to manage internal milestones.
- JCESR created **Research Integration** roles to craft internal and external efforts to strengthen and promote the JCESR team within the energy storage ecosystem.



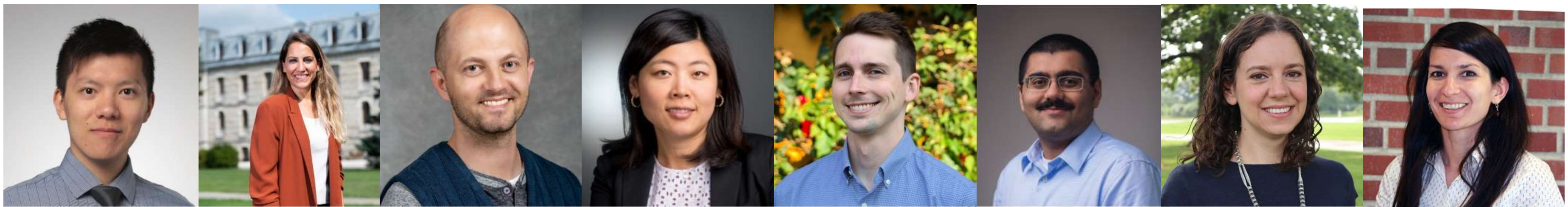
"Building a Better Battery": JCESR hosted 80 Chicago-area students and 7 teachers for full-day outreach event



2019 – 2023 JCESR Outreach Events

- **3 mentoring events** to encourage recruiting and diversity in STEM
- **8 scientific workshops** (2019-2022) bringing together scientific leaders and early career scientists to discuss emerging topics related to AI for energy storage, solid electrolytes, redoxmers, and the design of interfaces
- July 27, 2022 – ***Identifying Energy Storage R&D Challenges for Electric Aviation*** virtual workshop with RTRC to explore the fundamental electrochemical and system challenges to fully electric aviation
- April 4, 2023 ***– JCESR and Beyond: Translating the Basic Science of Batteries*** in-person showcase of JCESR innovation engaging the broader energy storage community

JCESR'S 350+ EARLY CAREER ALUMNI, UNIQUELY TRAINED IN A DIVERSE AND COMPREHENSIVE RESEARCH TEAM, WILL LEAD THE GLOBAL TRANSITION TO CLEAN ENERGY



Evonik | Boğaziçi Univ. | General Motors | ORNL | Univ. of Minnesota | CO School of Mines | Argonne | Univ. of Liverpool

- JCESR graduate students and postdocs have been immersed in heavily multidisciplinary teams – imparting the **breadth of expertise** required to bring new ideas and technologies to fruition, **collaboration skills**, and extensive professional **networks**.
- JCESR supported 135 Ph.D. degrees and 221 postdocs.

Where Are They Now?

53% industry

31% academia

12% National Laboratories

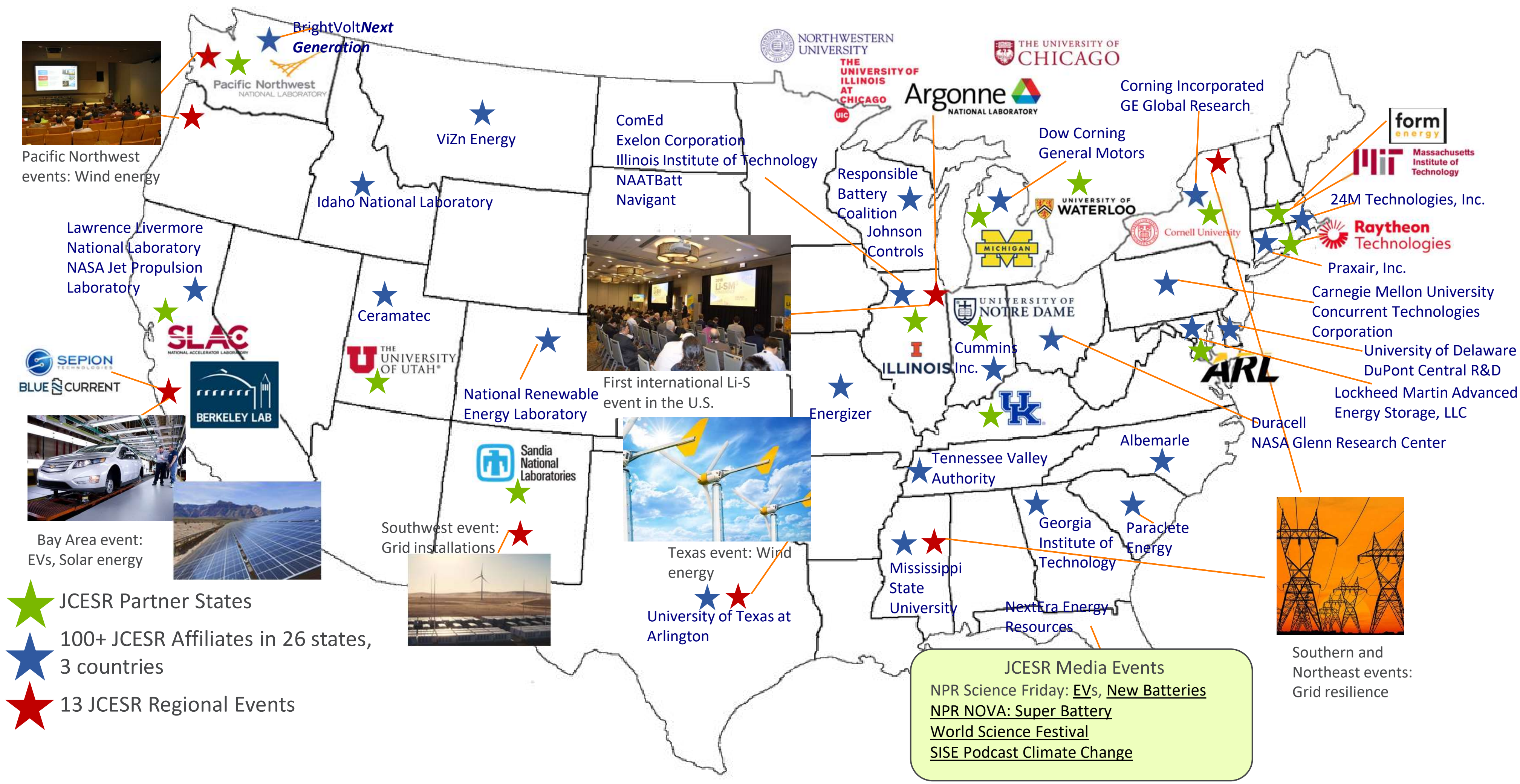
4% other (government, consulting, venture capital, journalism)

How meaningful is/was your JCESR experience?

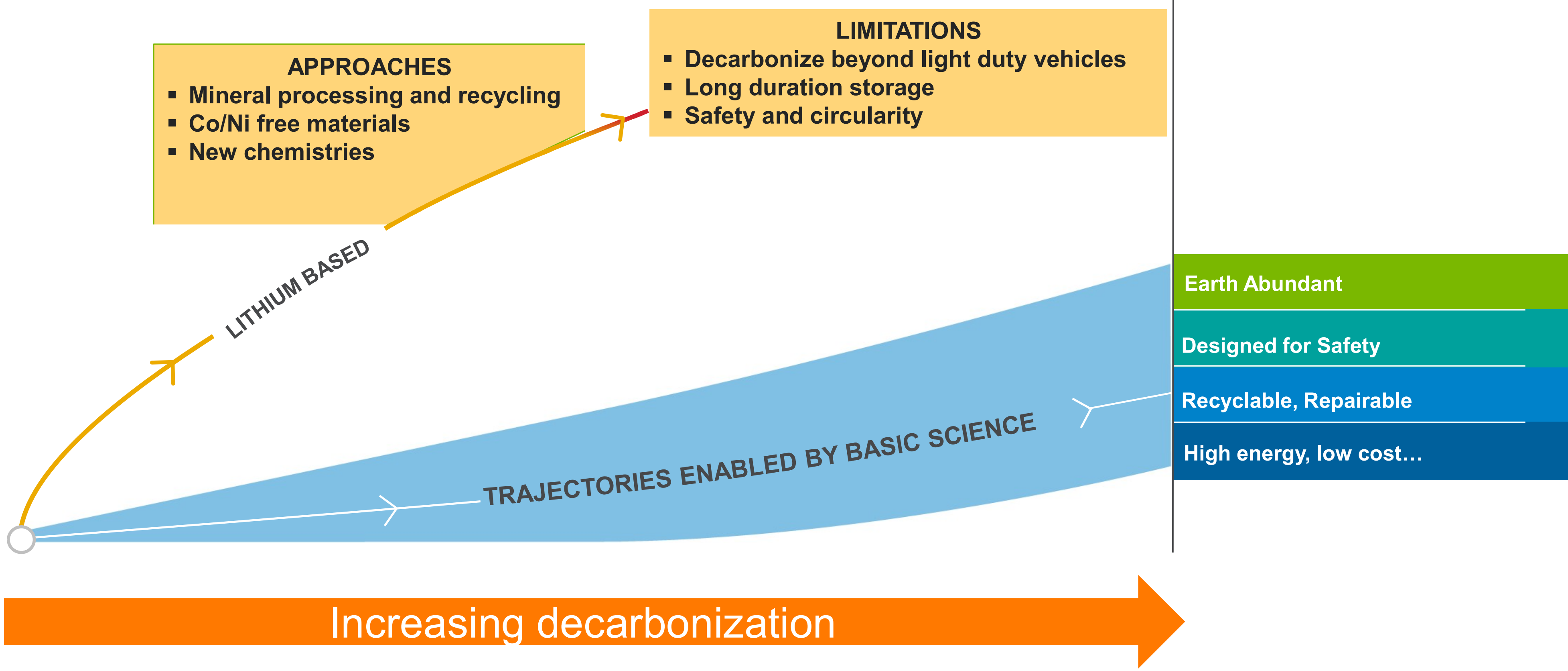
Responses from the JCESR Alumni…

- "JCESR provided me with broad exposure to battery science and a wide spectrum of collaborators and their perspectives. It made me a better scientist."
- "My training in JCESR was incredibly formative and allowed me to see more of the research process than I otherwise could have seen from my research group."
- "In addition to developing applicable skills, my JCESR experience has broadened my perspective around energy technologies, providing access to knowledge and exposure to fields I may not have otherwise experienced."
- "The network I gained has proven to be valuable over and over again. I have a strong network of folks in universities, national labs, and industry. This network has provided sources for recruiting new candidates to my team, consultant contracting work, proposal collaborators, and professional mentors."

JCESR'S NATIONAL REACH



Economy wide decarbonization requires a multi-pronged approach



THANK YOU