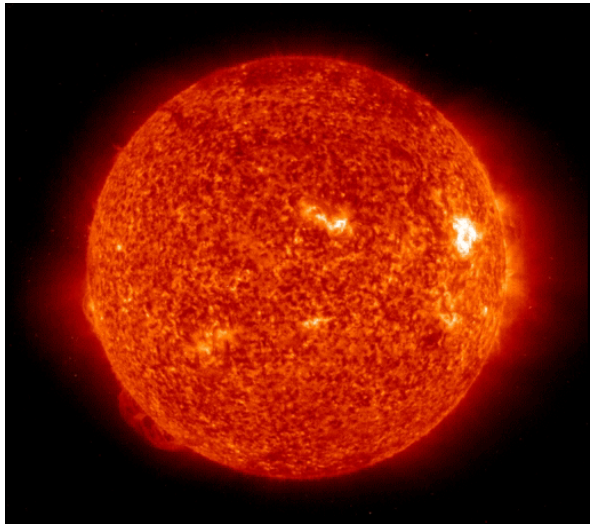
NAATBatt INTERNATIONAL

Research Trends/Needs for Future High Energy Density Battery Technology

M. Stanley Whittingham

Binghamton University (SUNY)



Solar PV and 3.3 GWh of battery Kern County, California

Moss Landing, California 2025

Powered by Lithium – our Neighbor Here

Several Major New Energy Storage Centers kicked off since last year

Non-Lithium Cells

DOE-BES Innovation Hub: Energy Storage Research Alliance (ESRA)

Argonne National Laboratory Led – Shirley Meng

Aqueous Cells

DOE-BES Innovation Hub: Aqueous Battery Consortium (ABC)

Stanford University Led – Yi Cui

Lithium Cells

NSF UpState New York Energy Storage Engine

Binghamton University Led

Leapfrog Asian Technology

Use-inspired R&D, Translation and Workforce training

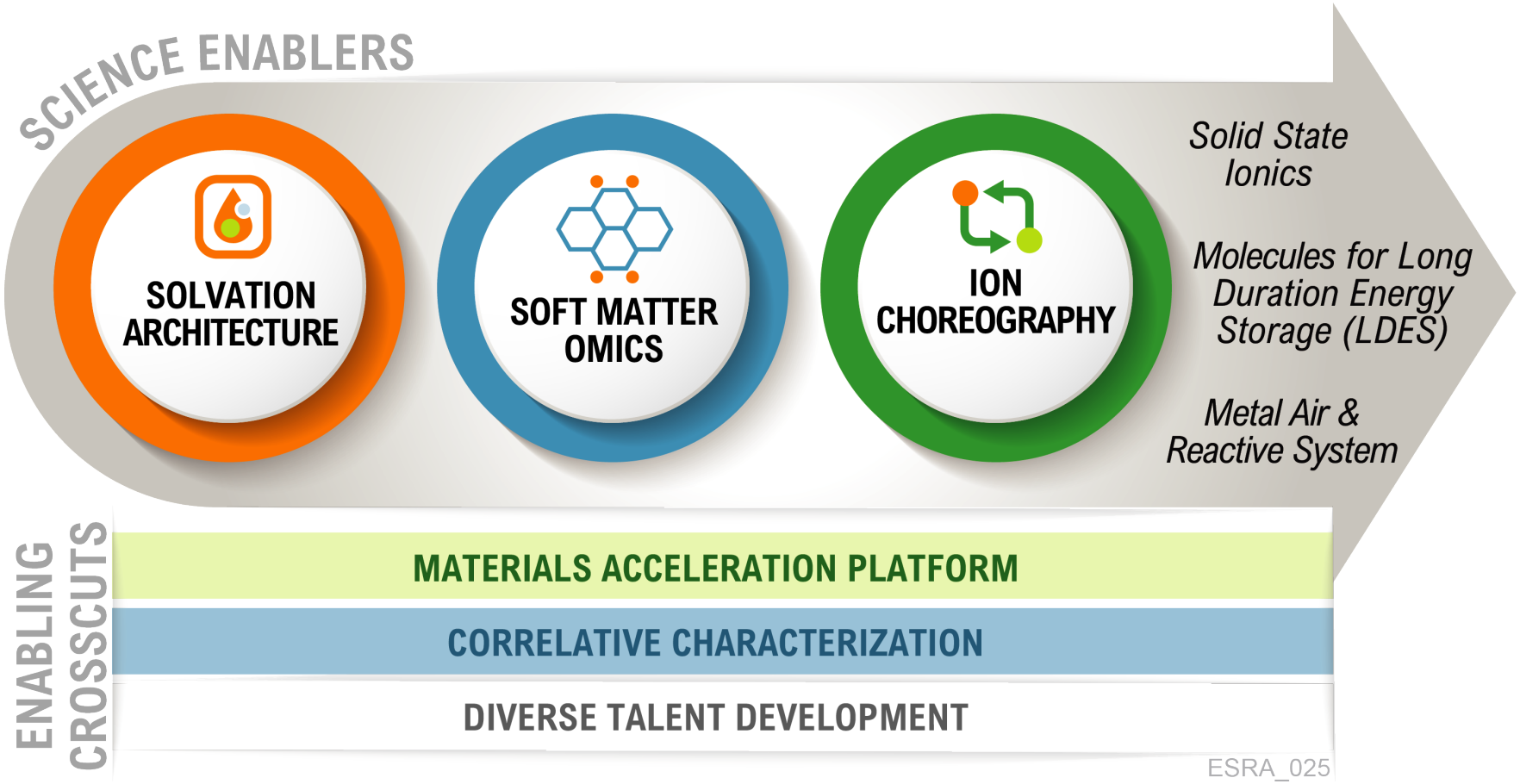
Major hub program of BES
12.5M$ per year for 5 years

ESRA Vision

To create an innovation ecosystem that enables discoveries in materials chemistry (beyond lithium) through fundamental understanding of electrochemical phenomena—laying the scientific foundation for breakthroughs in energy storage technologies

ESRA

Energy Storage Research Alliance



ESRA GOALS

- ✓ **Integrative and autonomous materials discovery with advanced AI**
- ✓ **Most cutting-edge facilities covering all relevant temporal and length scales**
- ✓ **Close to unity transference number in liquids**
- ✓ **Order-of-magnitude higher transport in soft matter**
- ✓ **Suppression of parasitic reactions in all solids**

Argonne NATIONAL LABORATORY · BERKELEY LAB Bringing Science Solutions to the World · Pacific Northwest NATIONAL LABORATORY · Columbia University · Duke University · MIT Massachusetts Institute of Technology · Princeton University · UC San Diego · The University of Chicago · University of Houston · University of Illinois Chicago · University of Illinois Urbana-Champaign · University of Michigan · Xavier University of Louisiana

An Energy Innovation Hub funded by DOE Office of Science Shirley Meng ESRA Director

Three Enabling Crosscuts

Facilitating the 3 Scientific Thrusts

Crosscut 1: Materials Acceleration Platform

- applies cutting-edge AI to automated synthesis and characterization to accelerate materials discovery in Zn and Na Electrochemistry

Crosscut 2: Correlative Characterization

- leverages the generational opportunities of APS-U and ALS-U to advance our ability to observe ion-matter motion and interactions at unprecedented temporal and spatial scales

Crosscut 3: Diverse Talent Development

- integrates the resources of ESRA's 3 national labs and 11 university partners to train, develop, and mentor next-gen workforce

Aqueous Battery Consortium (ABC)

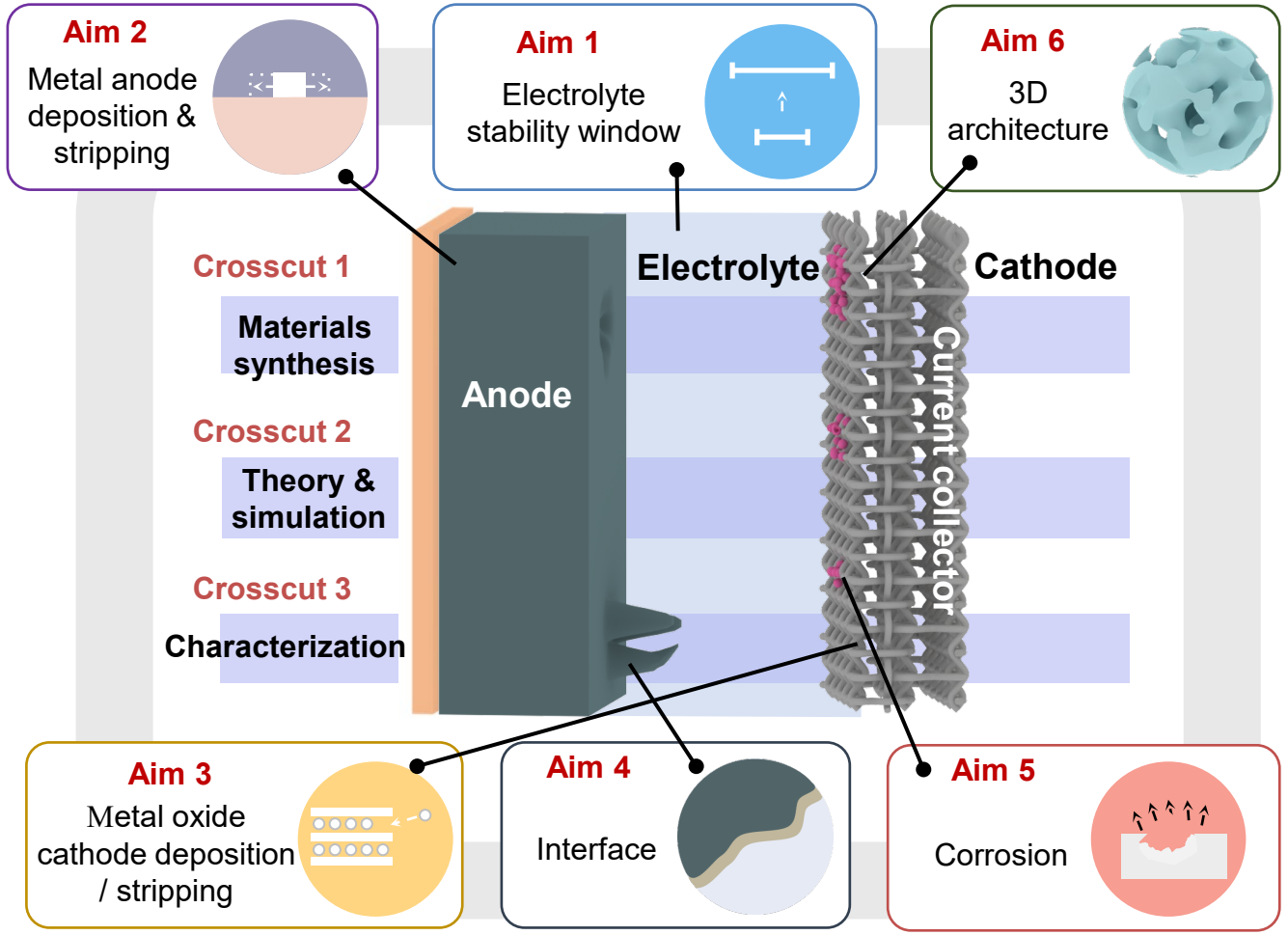
A DOE Energy Innovation Hub, $62.5M

Director: Yi Cui, Stanford University

The Aqueous Battery Consortium (ABC) will generate fundamental breakthroughs to enable aqueous batteries for long-duration energy storage with a potential of **10x reduction** in the cost floor compared with lithium-ion batteries, while ensuring **excellent safety** and **scalability (billions of ton)** for **global grid storage**.

Anodes: Zn, Mn, and Fe metal

Cathodes: MnO_2 and Fe_2O_3



Aqueous Battery Consortium

https://abc-hub.stanford.edu

Binghamton led teams will grow NYS's Energy Storage Ecosystem

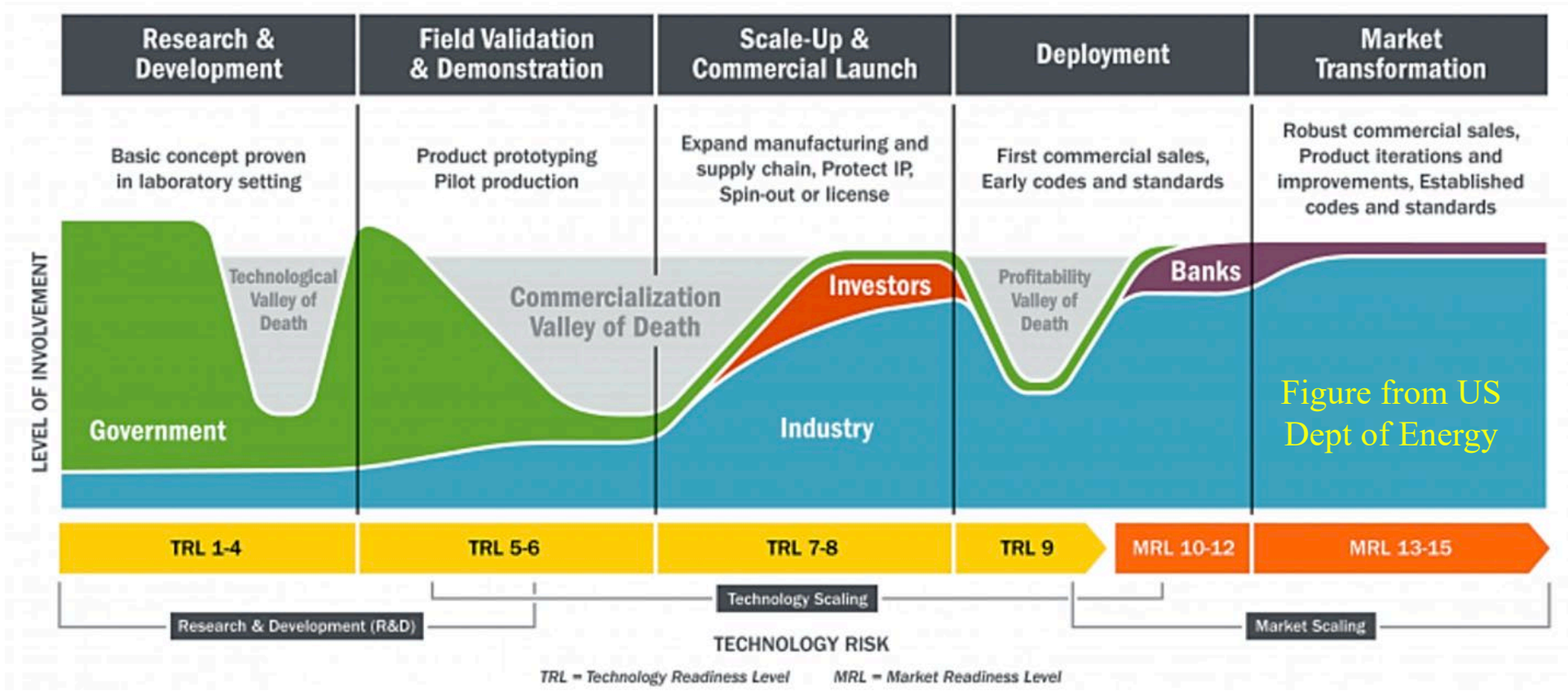


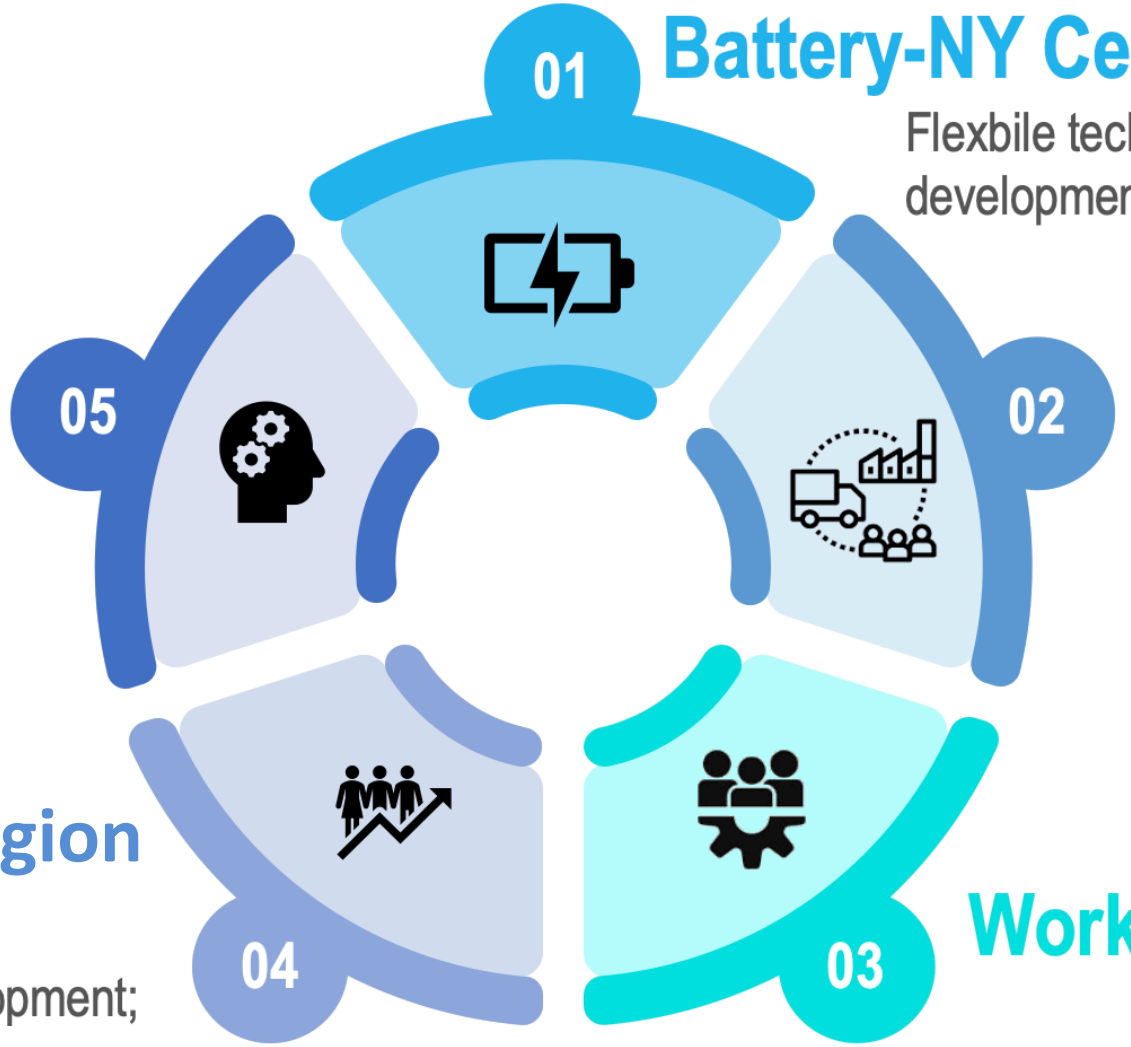
Figure from US Dept of Energy

NSF Engines Focused R&D $160M

EDA BBBRC Battery-NY $113M

EDA Hub Designation

New Energy NY Projects to Build the Ecosystem



01 Battery-NY Center

Flexbile tech and manufacturing development; 30 MWh pilot lines

02 Supply Chain

Grow, attract, and connect companies; Supplier qualification

03 Workforce Development

04 Rebuilding Region

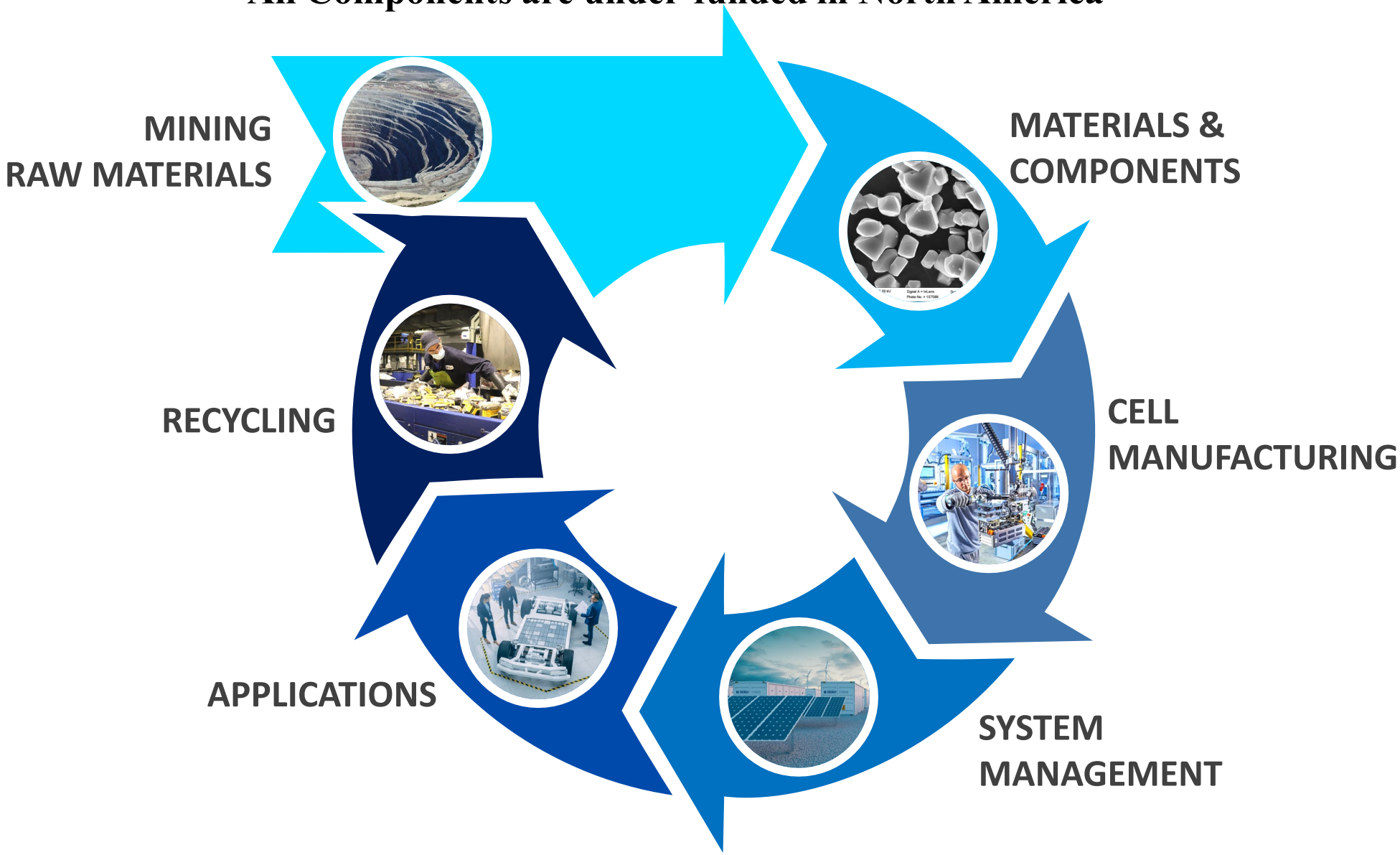
Brownfield development;

05 Acceleration

Technology innovation; Startup growth

The Life-Cycle Ecosystem for Lithium-Ion Batteries

All Components are under-funded in North America



2nd Step: a Joint Academia/Industry Effort to Leapfrog Today's Tech

NSF Engines Winner - *$160M* (10 years)

2. R&D to overcome hurdles

Binghamton University, State University of New York · RIT · Syracuse University · Cornell University · SUNY The State University of New York

Testing, Safety, and Manufacturing Equipment

intertek · RIT/BU · DELTAMODTECH® MASTERS IN MOTION®

Policy & Regulations

NY BES+ NEW YORK BATTERY AND ENERGY STORAGE TECHNOLOGY CONSORTIUM

A Technology Gap Analysis has Identified Promising Areas for Use-Inspired R&D

1. **Manufacturing process improvements**
    a. Reduction in the energy required to manufacture cells
    b. NMP-free electrode production process
        i. Ideally **dry processing**
    c. Thicker electrodes
        i. Higher ionic and electronic conductivity of active materials will be needed
    d. Improved operando **metrology** and **AI** to reduce manufacturing waste and improve safety
    e. American manufacturing **equipment**
    f. Design for recycling
        i. Direct recycling of components, with elimination of black mass
2. **Need systems that operate over wider temperature range**
    a. Eliminate thermal issues and air-conditioning for grid storage
3. **Safer systems**
    a. Recent major fires are jeopardizing the industry

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9 contracts signed for $2M

Future Trends for Sustainable/Safer Economic Energy

- ✓ **Lithium battery systems will dominate for next 5-10 years** (oxide and phosphate)
  - ✓ Trend back to "LFP, LMFP" for non-extreme applications
  - ✓ For high Ni NMC, how high is too high
- ✓ **Is sodium-ion safe?**
  - ✓ A number of reports are suggesting that sodium-ion cells explode on thermal runaway
- ✓ **Need systems that operate over wider temperature range**
  - ✓ Eliminate thermal issues and air conditioning
    - ✓ System efficiency could be raised from 70% to 90%
    - ✓ Safer
- ✓ **Not obvious that solid state is the answer**
  - ✓ Progress continues to be made