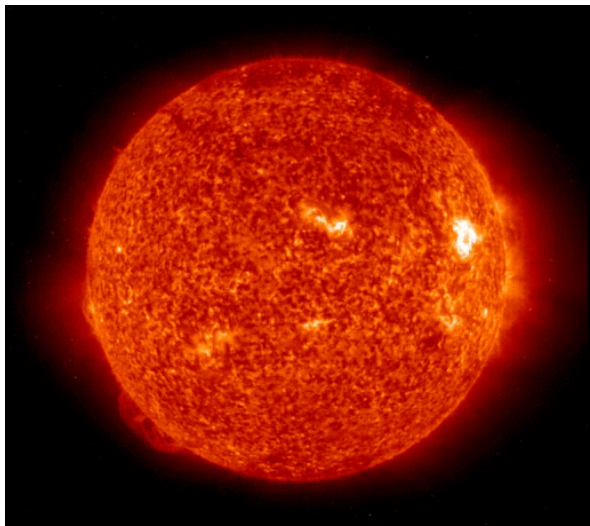




Research Trends/Needs for Future High Energy Density Battery Technology

M. Stanley Whittingham
Binghamton University (SUNY)



Solar PV and 3.3 GWh of battery Kern County, California



Alabama A&M, Huntsville



Vinfast, Hanoi

The Progress of Li/Na-Ion Intercalation Battery Science

Lithium-Ion Liquid Cells

Cathode Trends:

NMC: Drive continues toward higher **Nickel** continues

CATL using 811, and exploring single crystal material

Moving higher than 811 – maybe limit for Li metal

Major effort to reduce or even eliminate cobalt

Phosphates: Interest growing fast, driven by supply chain and cost

LFP hot now

Increasing effort on manganese analogs

More science work on vanadium phosphates and oxides

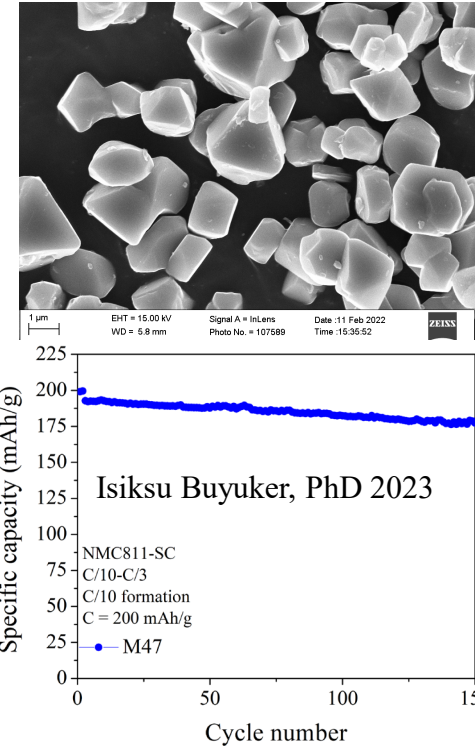
Anode Trends:

Silicon: Lots of investment, but little 3rd party verification (calendar life?)

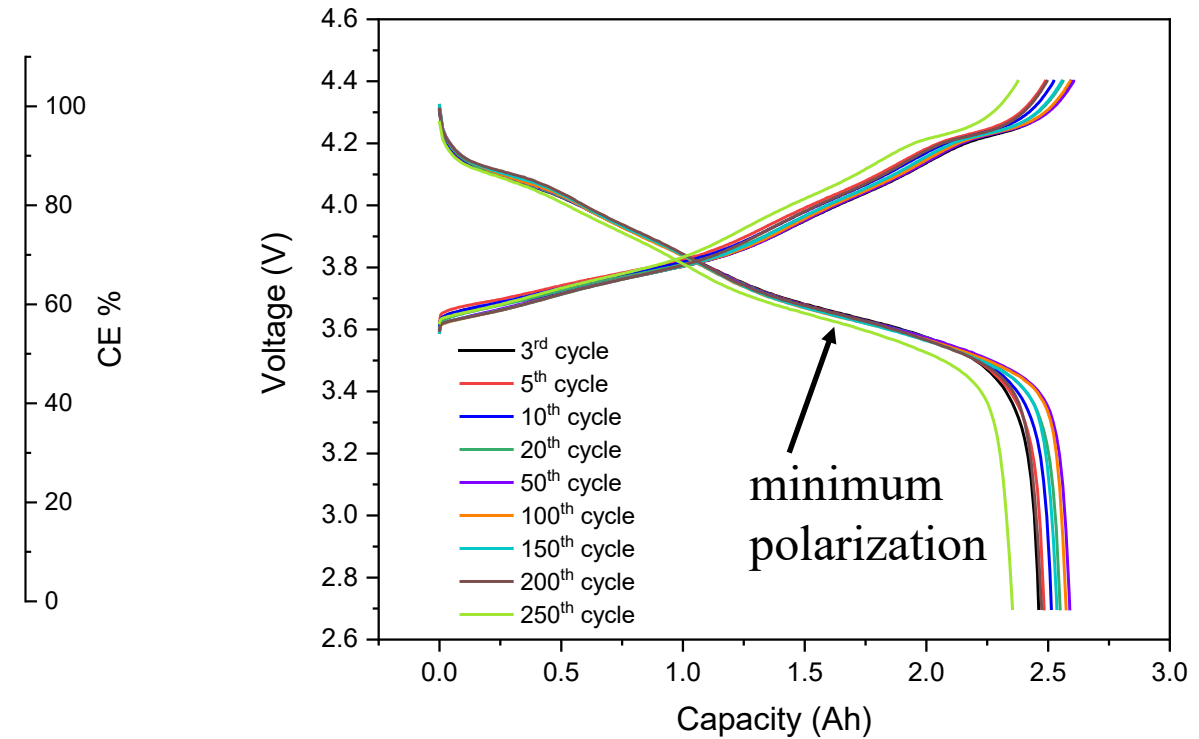
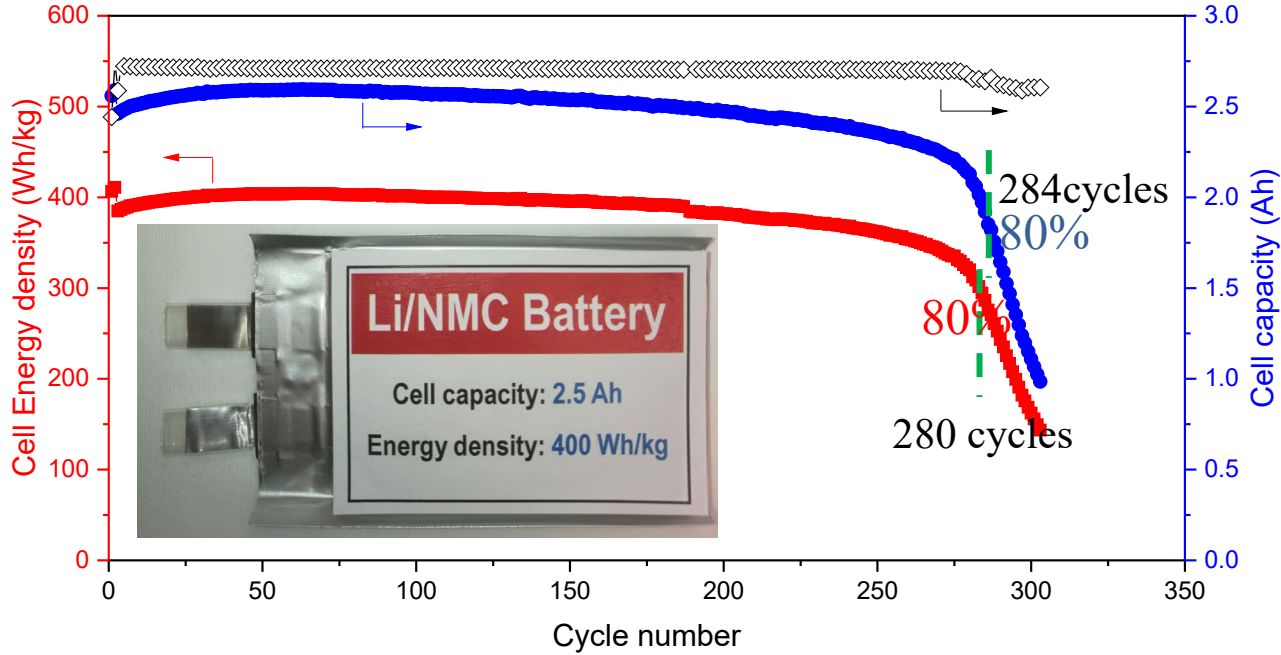
Lithium: Effort continues (Battery500 and Sion)

Sodium-Ion Liquid Cells

Growing science and commercial R&D activity; new DOE-EERE focus area (FOA out)



Battery500 Phase II: Achieving 400 Wh/kg with NMC 811 (MRS Bulletin December 2023)



- 2.5 Ah Li metal pouch cell with 400 Wh/kg cell-level energy and >250 stable cycles.
- Minimum polarization for the first 250 cycles: a significant improvement

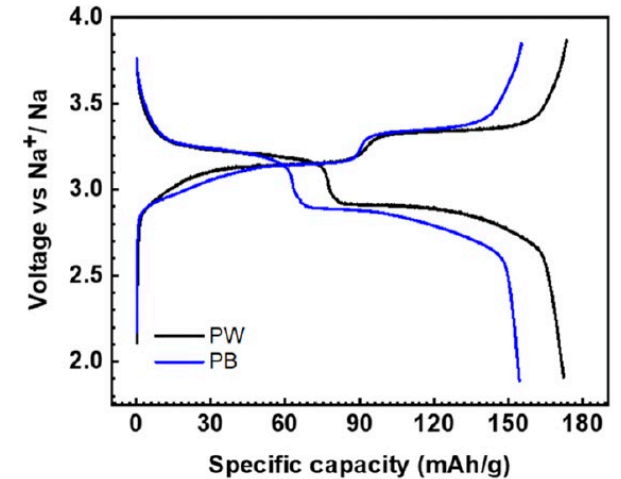
Formation: C/10 charge and discharge for 2 cycles
Subsequent cycling: C/10 Charge, C/3 Discharge 2.7-4.4V @25°C

Jie Xiao, PNNL



Status of Continuing Research on Sodium-ion Batteries

- ✓ **CATL and Natron pursuing ferrocyanides** (Prussian blue/white); $Na_2(Fe,Mn)[Fe(CN)_6]$
 - ✓ Capacity similar to LFP – 169 mAh/g
 - ✓ High rate
 - ✓ Low cost
 - ✓ CATL - Commercial facility 2023 (PW)
 - ✓ Natron – Commercial now (PB)
 - ✓ **Stability issues** (water, HCN, recycling)
- ✓ **Switch maybe to vanadium phosphates**
 - ✓ ? $Na_3V_2(PO_4)_3$
- ✓ **Is sodium lower cost?**
 - ✓ Hard carbon
 - ✓ Balance of system



Sustainability, the Electric Economy and Batteries

Lithium-Ion Batteries

40-80 kWh of energy to create 1 kWh of battery

Materials travel up to 50,000 miles from mine to final consumer

Need localized supply chain

Need greater attention to safety

Three BESS storage fires in NYS

Governor's study recommending fire code et al changes

No more NMP (and ideally fluorides)

Elimination of expensive “toxic” materials – e.g. cobalt

Replace by low cost abundant materials, like sulfur

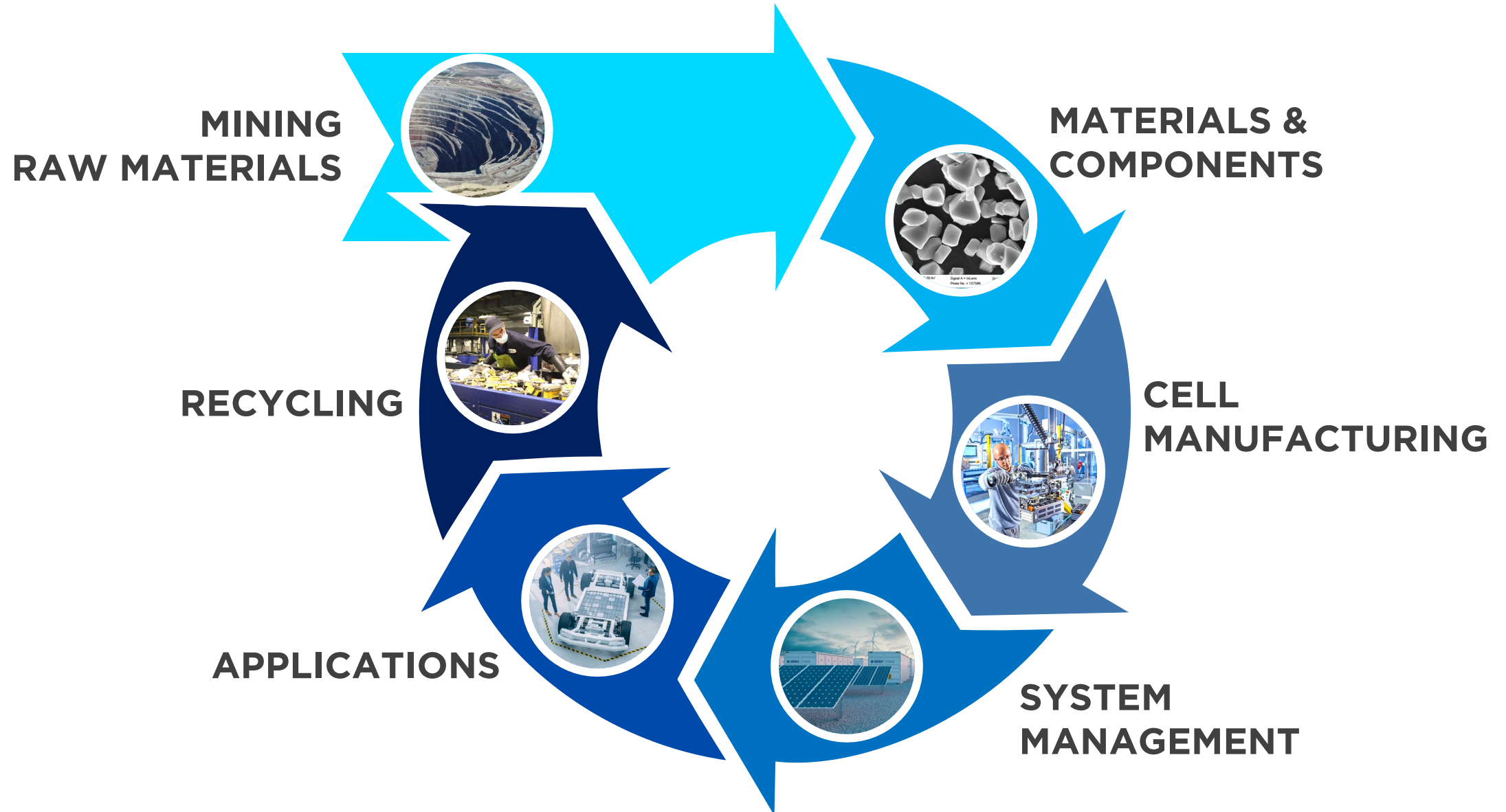
Leapfrog present Asian manufacturing processes

Dry processing with thicker electrodes (no more NMP)

Thicker electrodes need higher conductivity materials

Got to Go
NMP
PFAS
40-80 kWh

The Life-Cycle Ecosystem for Lithium-Ion Batteries

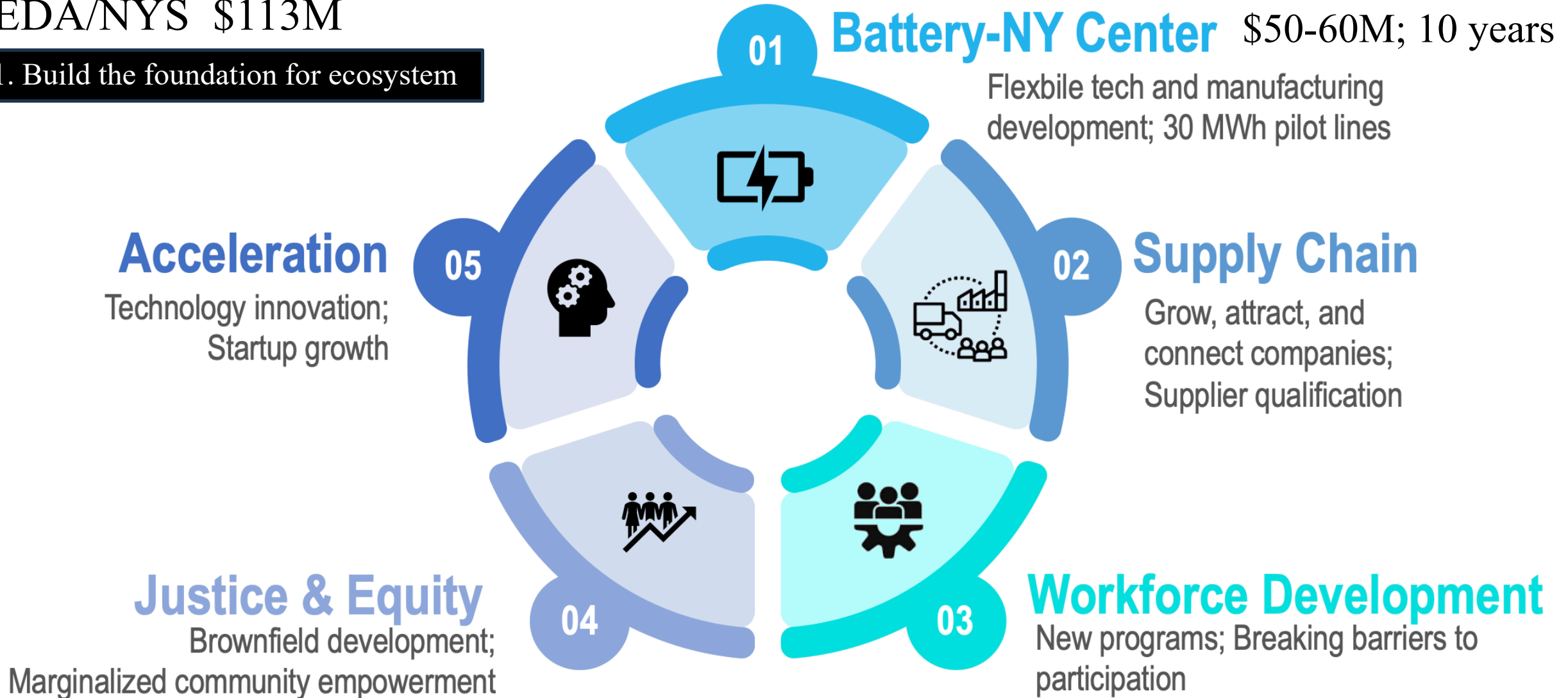


New Energy NY Projects to Build the Ecosystem



EDA/NYS \$113M

1. Build the foundation for ecosystem



Kick-off of New Energy New York and Battery-NY



October 20th, 2022



ALEJANDRA Y. CASTILLO @ IM3NY



SENATOR SCHUMER @ BINGHAMTON U



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

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

2. R&D to overcome hurdles



Testing, Safety, and Manufacturing Equipment



RIT/NYBEST



Policy & Regulations





NENY
new energy new york

AMERICA'S

**BATTERY
TECH HUB**



Future Trends for Greener/Safer Economic Energy

- ✓ **Lithium battery systems will dominate for next 5-10 years** (oxide and phosphate)
 - ✓ Fixed, no moving parts
 - ✓ Minimum maintenance
 - ✓ Trend back to “LFP, LMFP” for non-extreme applications, but **hydrogen** issues
 - ✓ For high Ni NMC, how high is too high
- ✓ **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

Battery-NY hired Executive Director: Paul Malliband

