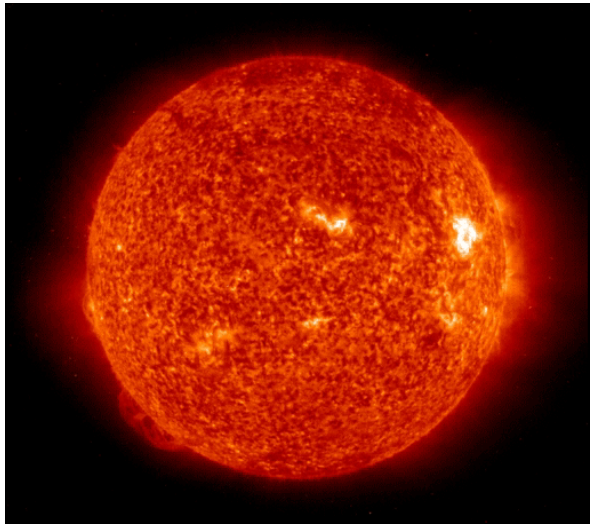
Report of Chief Science Officer

NAATBatt INTERNATIONAL

Research Trends for Future High Energy Density Battery Technology

M. Stanley Whittingham

Binghamton University (SUNY)



The Progress of Li/Na-Ion Intercalation Battery Science – Liquid Electrolytes

Lithium-Ion Liquid Cells

Cathode Trends:

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

- Moving higher than 811
- Major effort to reduce or even eliminate cobalt

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

- LFP hot now
- Some work on manganese analogs (iM3NY)
- More science work on vanadium phosphates and oxides

Anode Trends:

Silicon: Lots of investment, but little 3rd party verification

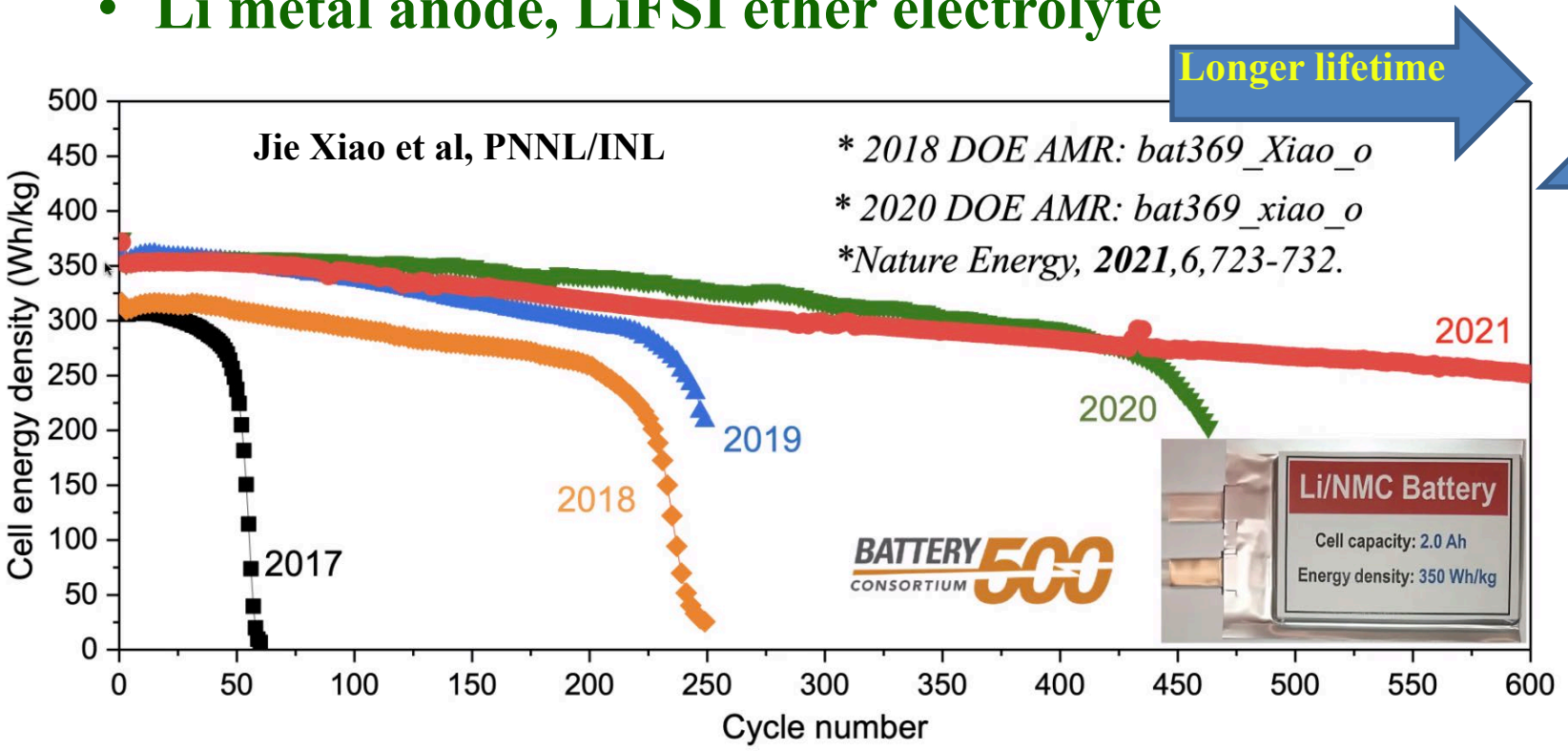
Lithium: Effort continues

Sodium-Ion Liquid Cells

Growing science and commercial R&D activity

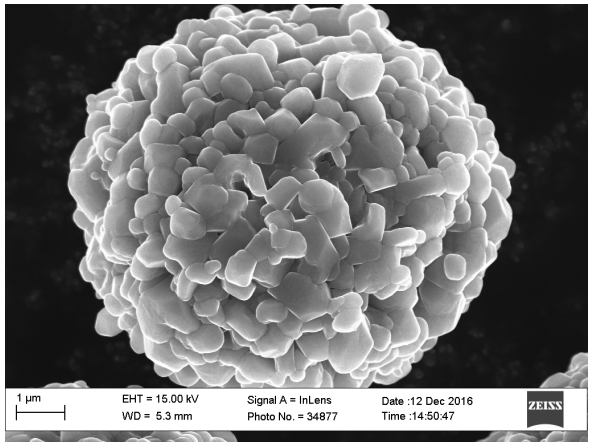
Battery500 Phase I: Achieved 350 Wh/kg with NMC622

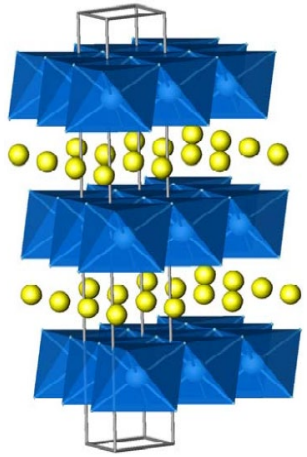
- NMC shows excellent cycling
  - Achieved 350 Wh/kg goal
  - Li metal anode, LiFSI ether electrolyte



Longer lifetime

Energy Density



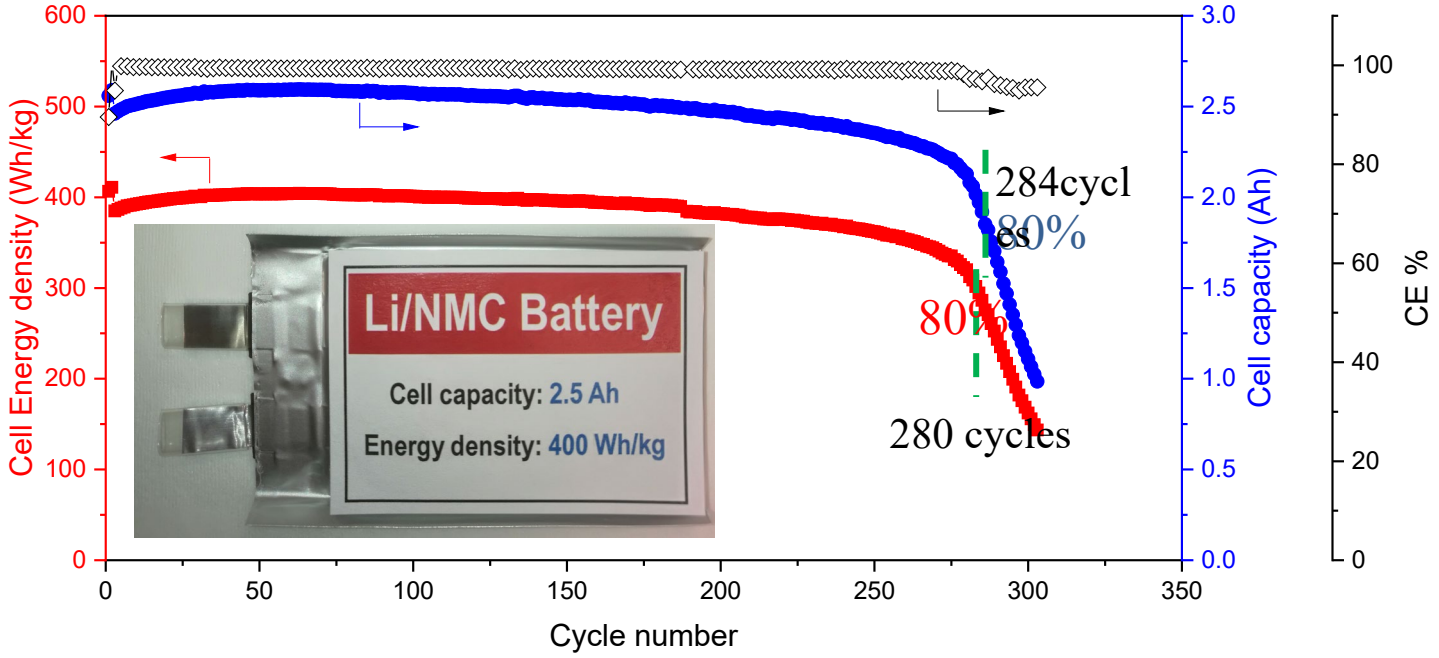


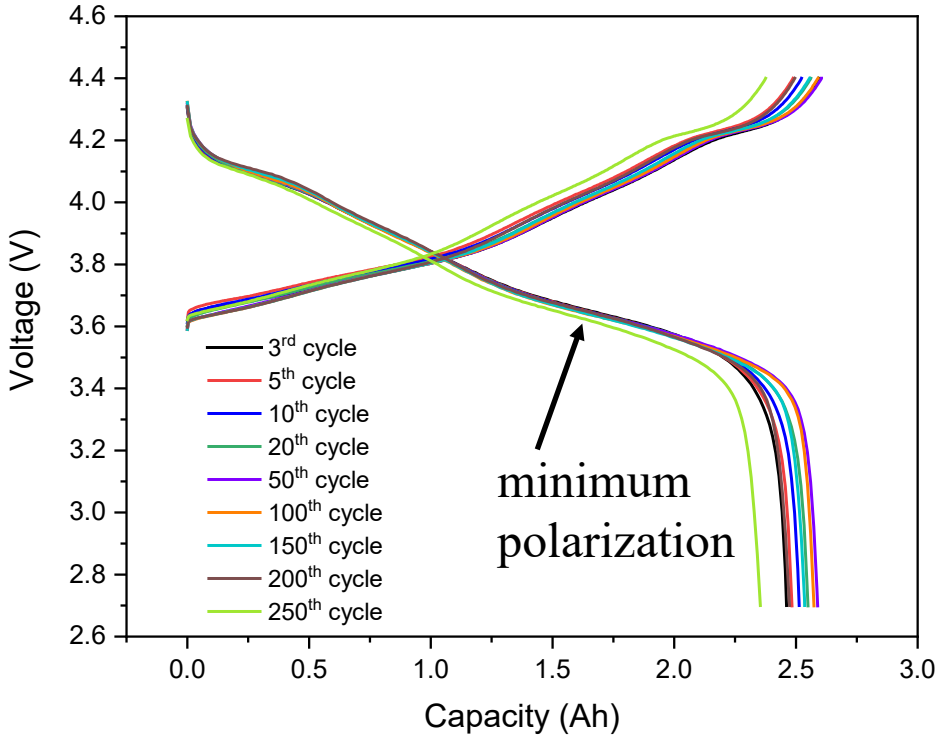
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

BATTERY 500 CONSORTIUM

BINGHAMTON UNIVERSITY
STATE UNIVERSITY OF NEW YORK

Battery500 Phase II: Achieving 400 Wh/kg with NMC 811





- FY22 **GPRA** milestone: 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

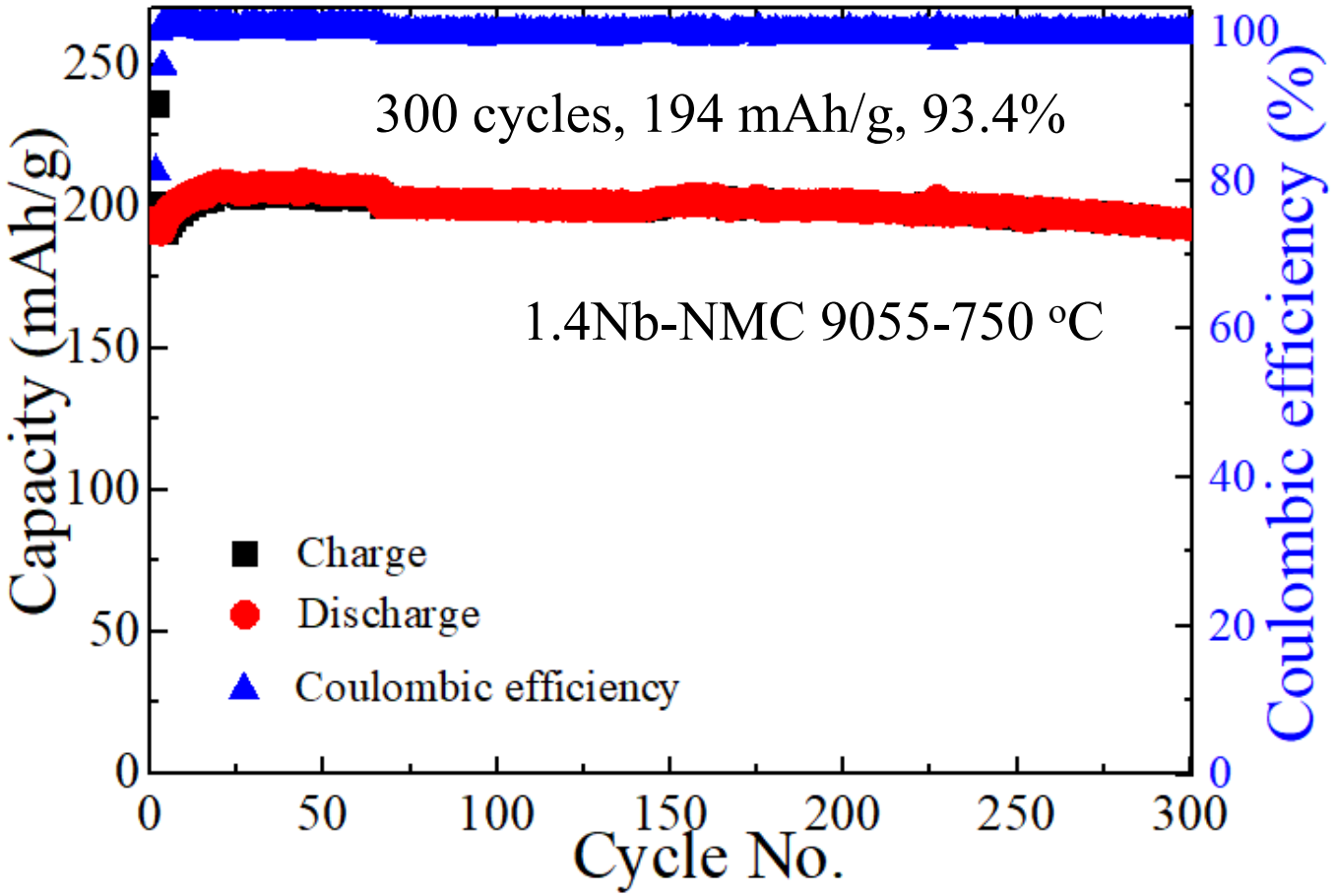
Formation: C/10 charge and discharge for 2 cycles
Subsequent cycling: C/10 Charge, 0.3C Discharge 2.7-4.4V @25°C

Jie Xiao, PNNL

BATTERY500 CONSORTIUM

Nb Modification Enhances Capacity Retention of 90%Ni NMC

2.8 to 4.4 V; C/10 charge and C/3 discharge;
PNNL (75 uL) ;13-15 mg/cm^2; Li foil

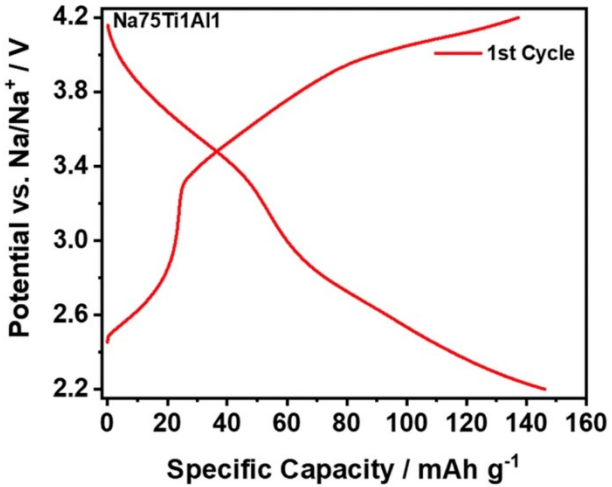


Charles Hatchett Medal

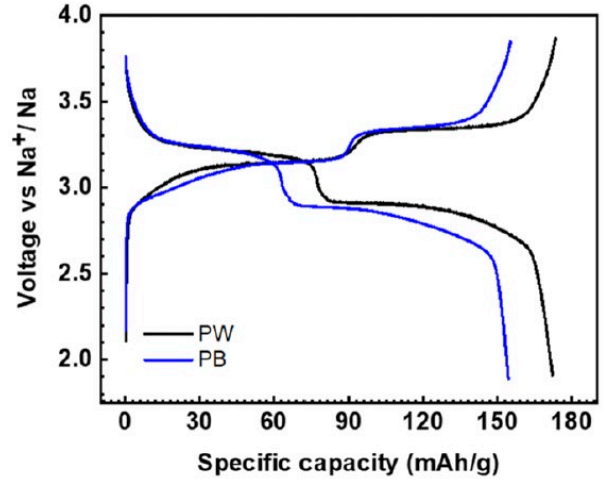
Fengxia Xin, BU

Status of Continuing Research on Sodium-ion Batteries

- ✓ **Faradion sold to Reliance Industries (India)**
  - ✓ Using nickel-based cathode, $NaNi_y[Mn,Mg,Ti]_{1-y}O_2$
  - ✓ Commercial unit in Australia, December 2022
  - ✓ Voltage change makes them unattractive
  - ✓ Claim that can be held at 0 volts (Na limited)
  - ✓ But, more hazardous on charge than Li-ion (98°C mp)



- ✓ **CATL and Natron are pursuing ferrocyanides** (Prussian blue/white); *$Na_2(Fe,Mn)[Fe(CN)_6]$*
  - ✓ Capacity similar to LFP – 169 mAh/g (CATL targeting 200 Wh/kg)
  - ✓ High rate
  - ✓ Low cost
  - ✓ CATL - Commercial facility 2023 (PW)
  - ✓ Natron – Commercial now (PB)



Energy Storage Critical to US Security and Freedom

INPUT

Equipment Manufacturers

Chemistry
(Acad, S/U, Industry)

Small R&D cells
(Tested at RIT/BU)
(<10 Wh)

Tomorrow: BATTERY-NY

New Manufacturing Approaches
to leapfrog Asia

Full-size "Pouch" and Cylindrical Cell Lines
to allow evaluation of "real" cells (kWh)

OUTPUT

Commercial Manufacturing *in* **Southern Tier of NYS** *and* **North America**

Grid Storage

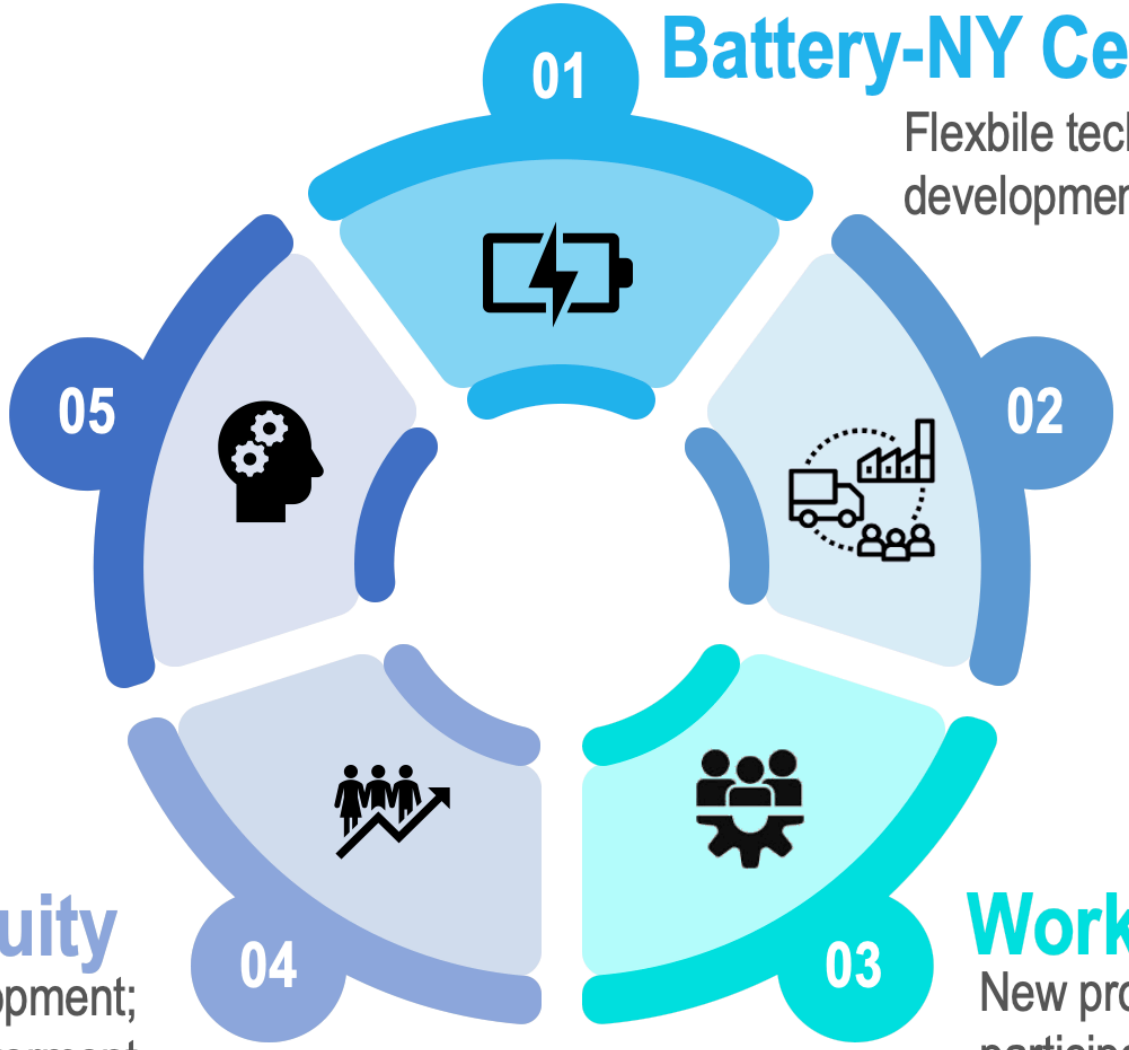
EVs

Electronics

Defense

New Energy NY Projects to Build the Ecosystem

EDA/NYS $113M



01 Battery-NY Center $50-60M; 10 years

Flexbile tech and manufacturing development; 30 MWh pilot lines

02 Supply Chain

Grow, attract, and connect companies; Supplier qualification

03 Workforce Development

New programs; Breaking barriers to participation

04 Justice & Equity

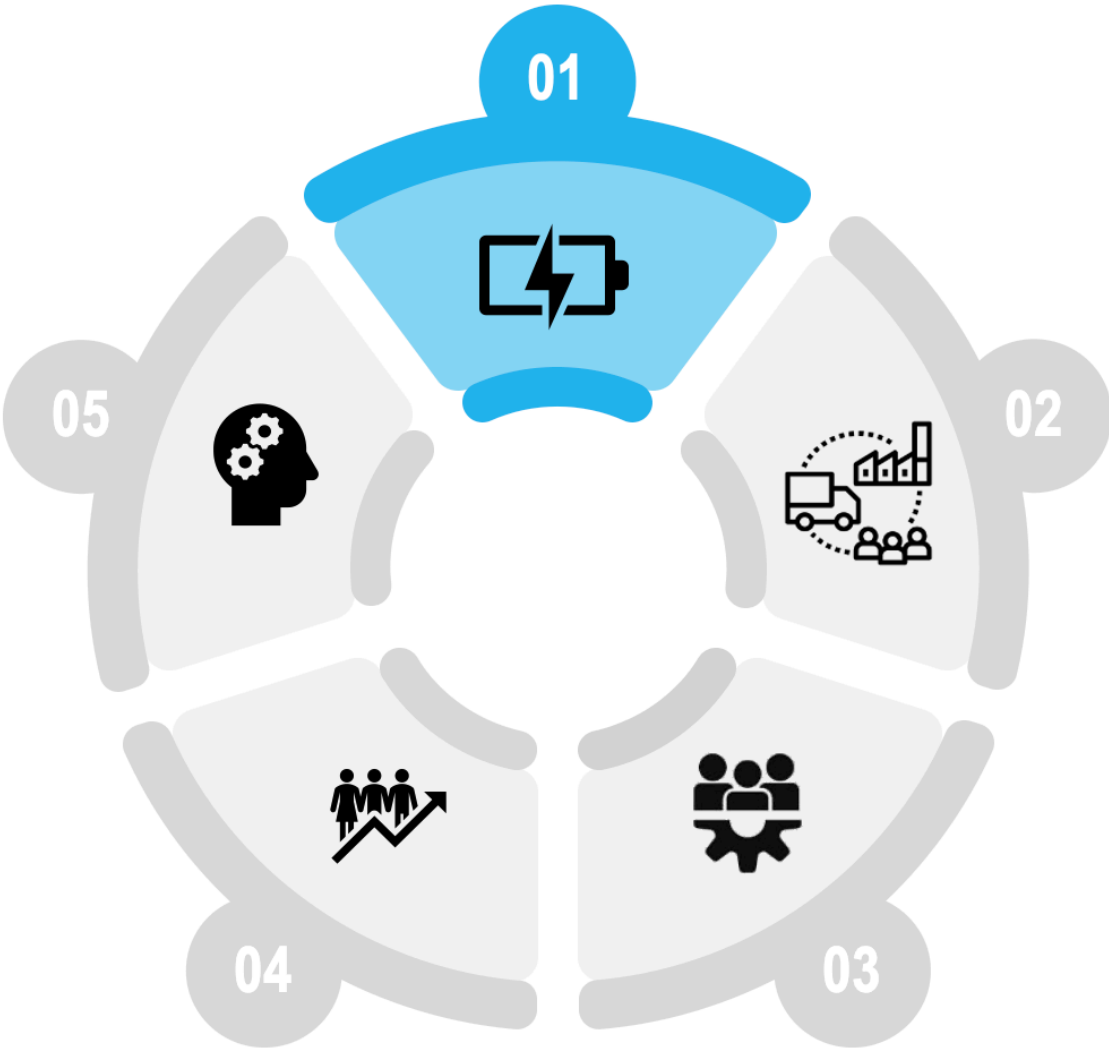
Brownfield development; Marginalized community empowerment

05 Acceleration

Technology innovation; Startup growth

Battery-NY Technology and Manufacturing Center

- ***Flexible technology development***
  - Encourage American equipment manufacturers
- ***Development and testing of new manufacturing methods***
  - Leapfrog the Asians
  - E.g. Eliminate bad actors, like NMP
- ***Industry demonstration scale***
  - 30 MWh pilot line
  - Pouch and cylindrical/prismatic



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

October 20th, 2022

ALEJANDRA Y. CASTILLO @ IM3NY

SENATOR SCHUMER @ BINGHAMTON U

Future Trends for Lower Cost/Safer Energy Storage

- ✓ **Lithium battery systems will dominate for next 5-10 years** (oxide and phosphate)
  - ✓ Fixed, no moving parts
  - ✓ Minimum maintenance
  - ✓ Trend back to "LFP" for non-extreme applications
  - ✓ 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 raised from 70% to 90%
    - ✓ Safer
- ✓ **Impact of Federal funding on science and technology**

Battery-NY looking for Executive Director