Sandia National Laboratories

Aqueous Zn-Based Batteries

PRESENTED BY

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DOE-OE Peer Review, Washington, D.C., August 5-7th, 2025

Presentation ID # 1004

U.S. DEPARTMENT of ENERGY

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SAND2026-15574C

Zn-Based Grid Storage Batteries

Project Goals: The objective for this program is to:

1.) Develop new knowledge, chemistries, materials, components, and methods for Zn-based batteries

2.) Demonstrate improved performance in prototype R&D cells with lower bill of material (BOM) costs

3.) Demonstrate compatibility with battery management systems (BMS)

4.) Translate these advances (in collaboration with industry) through low-cost US manufacturing to larger scale batteries, thereby advancing the development and commercialization of Zn-based batteries for US grid resilience and reliability

Zn batteries covered under this effort include:
Zn/MnO_2, Zn/Bi-CuO, Zn/Cu,Bi-MnO_2, Zn/Ni, Zn/air and 'Zn-ion' batteries

$Zn-MnO_2$

URBAN ELECTRIC POWER

1 MWh UEP alkaline battery backup system for the San Diego Supercomputer Center (CA).

ZĒLOS

Zn-Ni

ZincFive

ZAF Energy Systems

Æsir Technologies, Inc.

ENZINC

Zn-Air

Abound Energy Inc

ZINC8

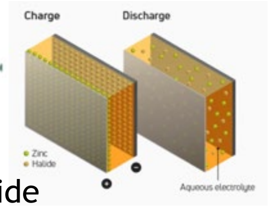
ZAF Energy Systems

e-zinc

Zn-Br

eos

35 MWh EOS Zn-Br system planned to provide 10-hour storage for microgrid with Indian Energy (CA).



redflow

Zn-Br flow battery installation

Zn-ion

SALIENT ENERGY

coulomb TECHNOLOGY

enerpoly

Zn-Based Grid Storage Batteries

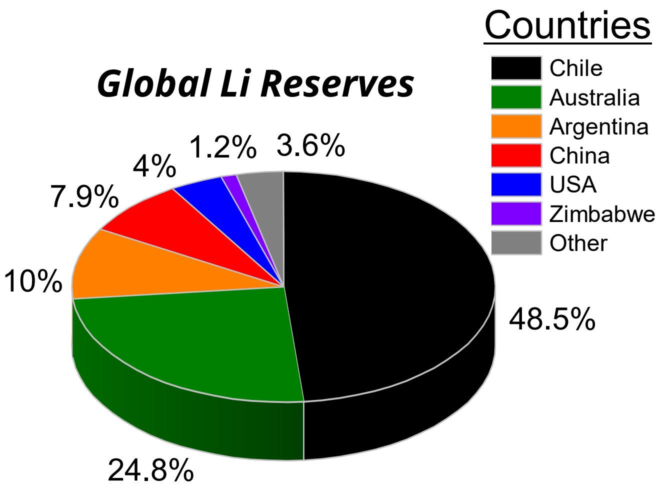
Current Practice:

Grid Storage is currently dominated by Li-ion batteries (high energy density and cycling stability)

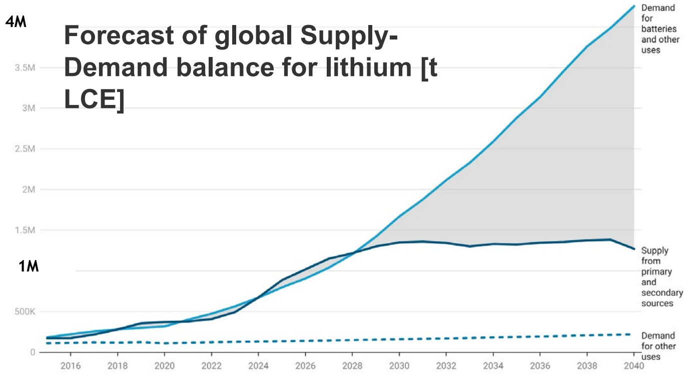
- Significant cost, supply chain and safety concerns
- Typically limited to $\leq$ 4 h of duration.

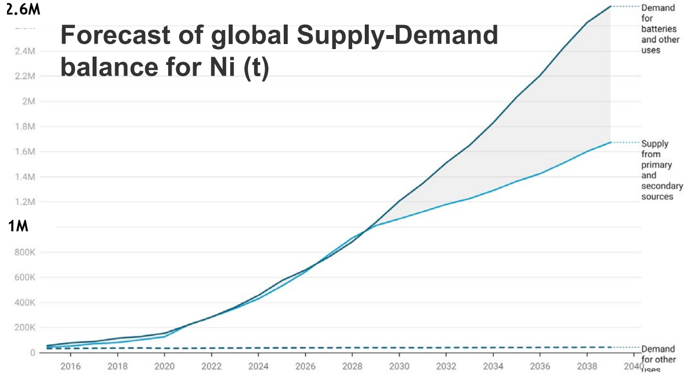
Zinc Batteries have the potential to provide reliable, safe, domestically sourced energy generation to strengthen the US electrical grid

- Non-flammable electrolytes (*i.e.* aqueous)
- Based solely on abundant materials
- Fundamental limitations of Zn battery chemistries still need to be determined to reliably realize > 5000 cycles (~ 10-15 years of battery life).



Source: BP Statistical Review of World Energy, 2021





https://www.technologyreview.com from May 2, 2024

https://www.iea.org/reports/batteries-and-secure-energy-transitions

Zn-Based Grid Storage Batteries

Why Sandia and Team ?

- Strong combination of material science, engineering, and chemistry knowledge with significant experience in zinc-based batteries including tech maturation and industrial partnerships
- Success in forming strategic partnerships and expertise with proven access to advanced characterization capabilities including access to DOE national user facilities (CINT, NSLS-II(QAS, ISS, XPD, HEX *et al.*) etc.)

Sandia National Laboratories

Timothy Lambert

Zn Battery Development

Igor Bezsonov, Jason Huang, Calvin Quilty, Ciara Wright, Lauren To

Sandia National Laboratories

Cy Fujimoto

Membranes/Separator Development

Sandia National Laboratories

Bryan Wygant

Zn-air

Jeremy Espano

Sandia National Laboratories

Amalie Frischknecht

Molecular Modeling of Electrolytes for Earth-Abundant Batteries

Storage Innovations 2030 Partner

Stony Brook University

Prof. Amy Marschilok
Prof. Ken Takeuchi

Prof. Esther Takeuchi

Deepak Kharel

Prof. Yang-Tse (YT) Cheng

Prof. Joshua Gallaway

Advanced Characterization

Yogeshwaran Agilan,
Erik Zimmerer

Storage Innovations 2030 Partner

Prof. Nian Liu

Metal-ion Battery Development

Zhitao Chen

Storage Innovations 2030 Partner

CUNY The City University of New York

Energy Institute

Prof. Sanjoy Banerjee

Electrode and Electrolyte Development

Patrick Yang, Erfan Mohebolkhames, Debayon Dutta

Lawrence Livermore National Laboratory

Cheng Zhu

Scalable manufacturing of 3D structured zinc anodes for zinc metal batteries

Tony Van Buuren

FY25/26: Sandia is establishing the High-capacity long Duration Energy storage Zinc battery consortium (**HiDEZ**)

Partnering with:

- EverZinc and Borman specialty Materials
- Innate Energy, Coulomb Technology, Octet Scientific, e-Zinc U.S. Inc.
- The International Zinc Association's Zinc Battery Initiative (ZBI), Ørsted North America, Consolidated Edison, Inc., New York Power Authority, Energy DELTA Lab.

Zn-Based Grid Storage Batteries

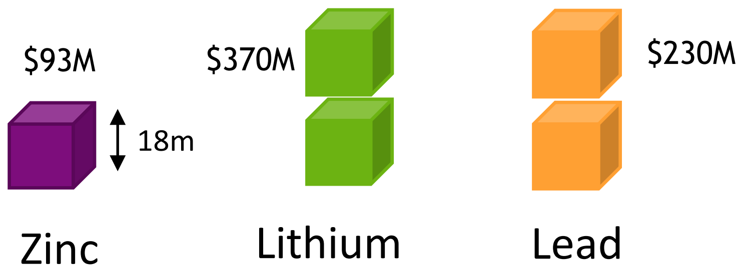
Innovation:

- Gain control of the conversion chemistry reactions through fundamental understanding
- & Higher utilization of active materials in Zinc-based batteries
- Successful rechargeable Zinc-based battery development
- Chemical species that provide valuable mechanistic information are often interfacial or amorphous
- Challenging to detect or monitor
- Comprehensive approach: electrochemistry, materials science, advanced characterization, and simulation/modeling are all required to advance the technology.

Impact:

Zinc batteries have higher theoretical volumetric energy than both Pb and Li-ion batteries but with significantly lower cost and greater safety.

Volumes/Cost for Equivalent 60,000 MWh Energies



Alignment:

Inexpensive rechargeable Zn-based batteries that can be sourced and manufactured in the US will support DOE’s mission to: strengthen our nation’s power grid to maintain a reliable, affordable, secure, and resilient electricity delivery infrastructure.

Electrochemical Grid Storage ‘Requirements’

- Low cost: < $100/kWh
- 2 to > 10 h worth of storage for grid resiliency and reliability
- Low-risk components: earth-abundant, minimally processed, available supply chain (sourced in USA!)
- Easy to manufacture – roll to roll manufacturing? (made in USA!)
- Long cycle (and shelf) life: Tens of years of operation
- Safe
- High energy density **

*** Energy = Voltage (V) x Capacity (mAh/cm^2)*

Lower voltage systems require higher capacities to be competitive
Zn/MnO_2 : 15 mAh/cm^2 to achieve similar energy density to a lithium cobalt oxide (LCO) battery with 1-5 mAh/cm^2 active loading

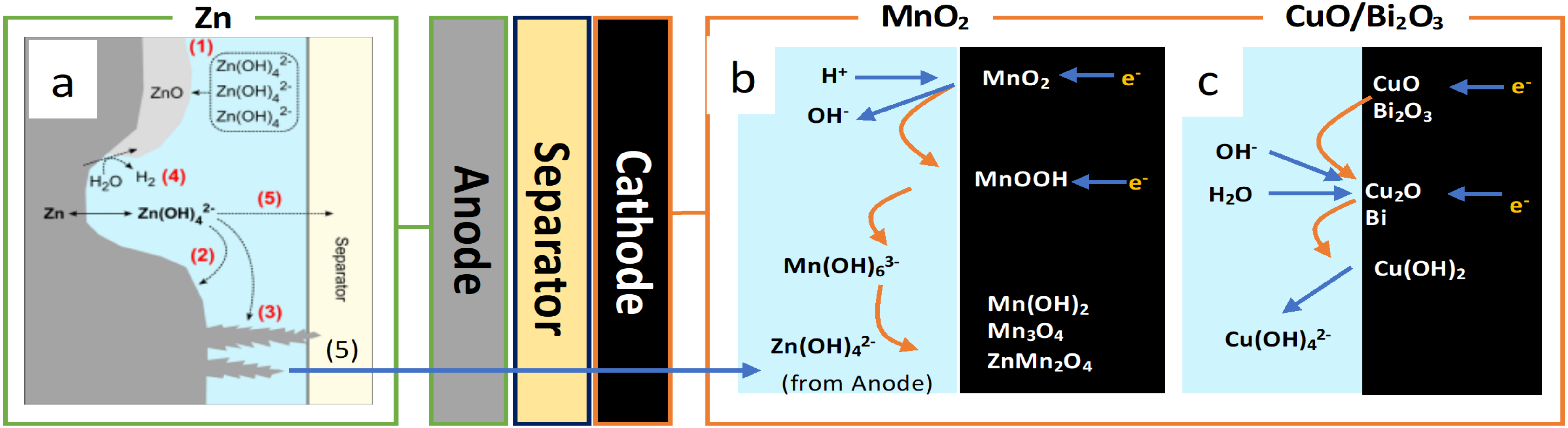
(Higher Voltage aqueous batteries also of interest)

M. B. Lim et al. Rechargeable alkaline zinc-manganese oxide batteries for grid storage: Mechanisms, challenges and developments. doi.org/10.1016/j.mser.2020.100593.

Low-Cost Aqueous Batteries Based on Zinc

Obtaining High DOD at both electrodes for thousands of cycles remains a challenge

How does one obtain reliable high-capacity conversion chemistry in aqueous Zn batteries ?



Adapted from "*A Critical Comparison of Mildly Acidic versus Alkaline Zinc Batteries*" *Acc. Mater. Res. 2023 4, 4, 299-306.*

*Controlling ion and electron movement (**with meaningful capacities) in the electrode/cell is crucial*

Zn Anode – conversion electrode

(1) passivation, (2) shape change (3) dendrite formation, (4) H_2 evolution (5) $Zn(OH)_4^{2-}$ crossover

Cathode - conversion electrode

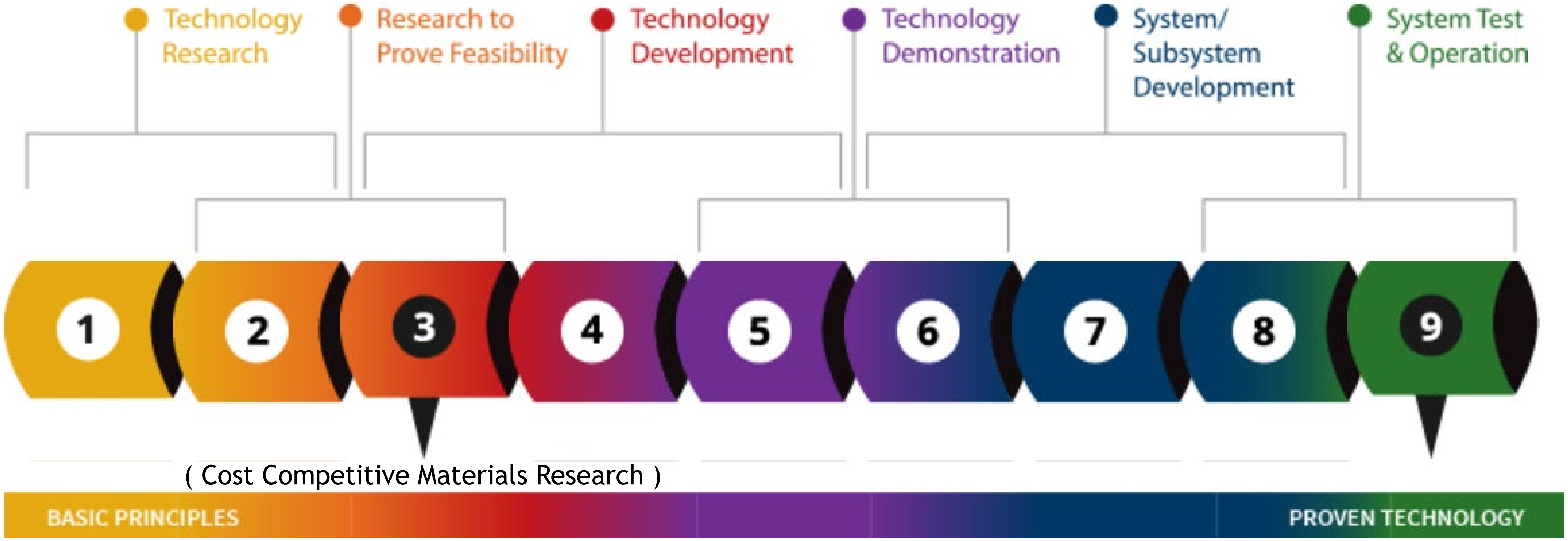
(1) **MnO_2** crystal structure breakdown, $Mn(OH)_6^{3-}$, irreversible phases, susceptible to Zn poisoning

(2) **CuO** Cu_2O reversibility, soluble $Cu(OH)_4^{2-}$ leads to capacity loss

Separators and Electrolyte

Crossover of soluble "ate" complexes, dendrite shorting, *controlled SEI, Higher ECW and Battery Voltage*

Approximate Technical Readiness Levels (TRLs) for Zn-Battery Projects



Collectively we work in the TRL 1-4/5 realm

(Other OE funded efforts)

PROJECT TEAM - RESULTS

RESULTS: (SNL) Zn Project Battery Posters - DOE OE Energy Storage Peer Review 2025

11 Posters

SNL led Posters:

1. A. Frischknecht et al. “Molecular Simulations of Gas and Ion Transport in Potassium Polyacrylate Electrolytes”
2. J. Espano “Nickel Sulfoselenide Electrocatalysts for Flowing Zn-Air Batteries”
3. I. Bezsonov et al. “New Capabilities in Zinc Battery Testing”
4. C. Quilty et al. “Unraveling the Role of Layered ZHX Materials in Zn-Ion Battery Cycling”
5. J. Huang et al. “Separator Evaluation for Alkaline & Mildly-acidic Zn-based batteries”

NU-led Poster:

6. Y. Agilan et al. “Development of Copper Oxide Cathodes for Rechargeable Alkaline Zinc Batteries”

GTech-led Poster:

7. Z. Chen et al. “Electrode and Electrolyte Modification Towards Rechargeable Aqueous Batteries”

CUNY-EI led Posters:

8. D. Dutta et al. “Mildly Acidic Acetate-Based Electrolytes for Zinc-Ion Batteries””
9. P. Yang et al. “Cycling and Failure Mechanisms of Rechargeable Alkaline Calcium Zincate ($CaZn_2(OH)_6 \cdot 2H_2O$) Anodes for Grid Storage Applications”
10. E. Mohebolkhames et al “Low-Cost Zinc-Ion Battery with Carbothermally Modified MnO_2 Cathode”

LLNL led Poster:

11. C. Zhu et al. “Large-Scale, Structured 3D Zinc Anodes for Zinc Batteries”

Highlights

Sandia National Laboratories — ZHX, electrolyte Development and imaging (CINT)

CUNY The City University of New York — High Cycle Life Low-Cost Calcium Additive Anodes That can be Produced *via* Roll-to-Roll Manufacturing

Lawrence Livermore National Laboratory — Scalable Manufacturing of 3D Structured Zinc Anodes for Zinc Metal Batteries

Northeastern University, Boston, Massachusetts — Lux Veritas Virtus

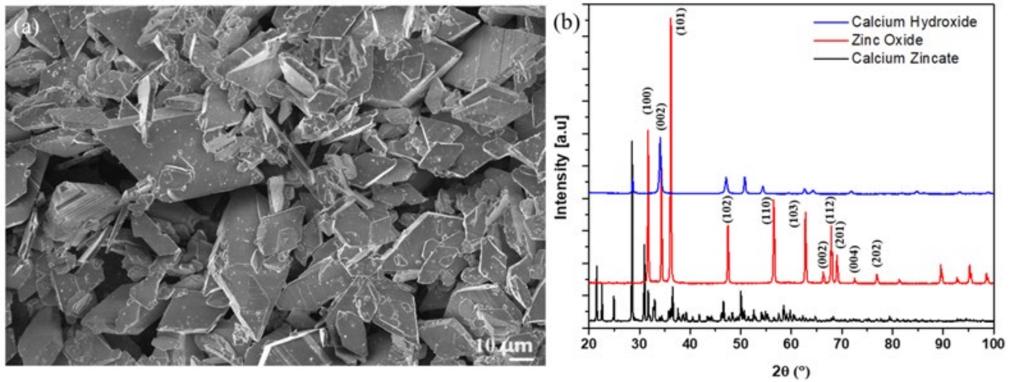
GT

Highlight – High Cycle Life Low-Cost Calcium Additive Anodes That can be Produced *via* Roll-to-Roll Manufacturing

Goal: Evaluate cycling and failure mechanism for CaZn electrodes at 50% DOD

$$2Zn(OH)_4^{2-} + Ca(OH)_2 + 2H_2O \rightleftharpoons CaZn_2(OH)_6 \cdot 2H_2O + 4OH^-$$

Phase pure (>98%) CaZn synthesized

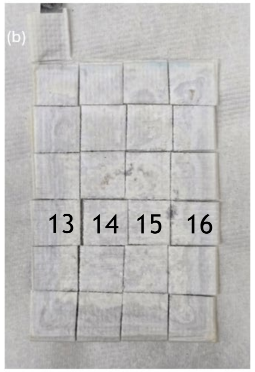


At 70% capacity, significant shape change (migration)

(a) Weight (g)

0.184	0.108	0.133	0.153
0.158	0.160	0.213	0.142
0.210	0.496	0.502	0.219
0.219	0.385	0.334	0.214
0.229	0.362	0.376	0.237
0.168	0.208	0.212	0.154

Low — High



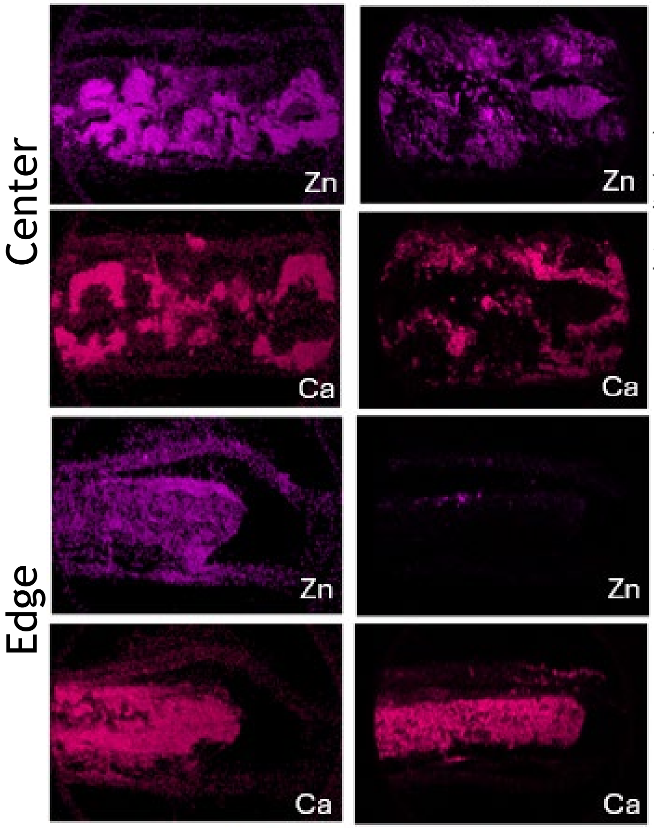
(c) Thickness (thousandths of an inch)

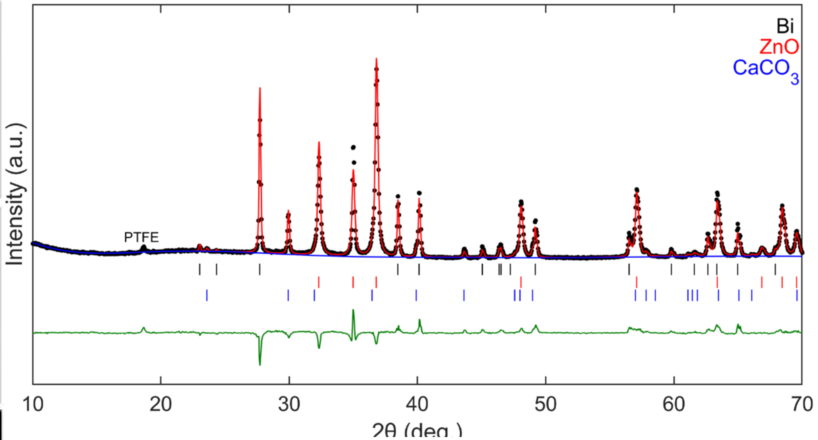
0.0460	0.0390	0.0450	0.0470
0.0465	0.0475	0.0545	0.0480
0.0550	0.0575	0.0575	0.0525
0.0540	0.0565	0.0455	0.0540
0.0525	0.0545	0.0450	0.0525
0.0490	0.0550	0.0500	0.0530

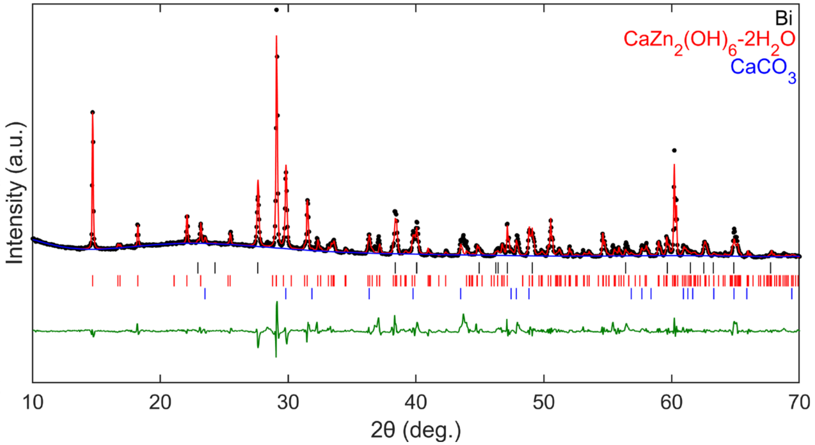
Low — High

Failure through heterogeneity:

- Migration of Zn and Ca species
- Breakdown of CaZn structure







0% Zn "Discharged" (100% CaZn)

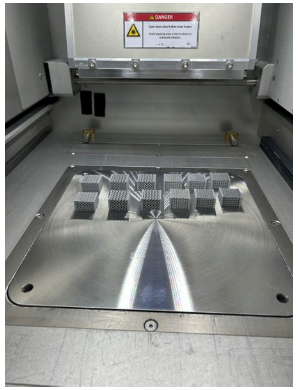
P. Yang *et al*. "Unraveling the Cycling and Failure Mechanisms of Alkaline Rechargeable Calcium Zincate ($Ca[Zn(OH)_3]_2 \cdot 2H_2O$) Electrodes" **2025** EES Batteries. *manuscript to be submitted.*

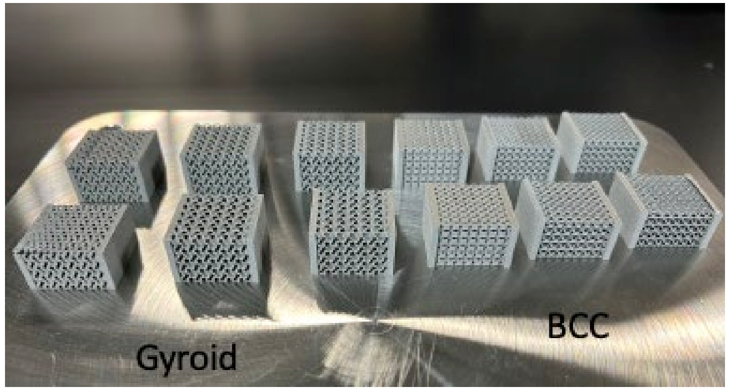
w/CCNY

Highlight - Scalable Manufacturing of 3D Structured Zinc Anodes for Zinc Metal Batteries

Scale-Up Printing of 3-D monoliths *via* Laser Powder Bed Fusion

10" x 10" area



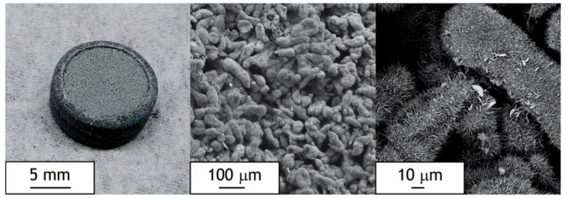


~ 60-70% porosity

60% = ~ 2342 mAh/cm^3

26 - 34% DOD = 600-800 mAh/cm^3

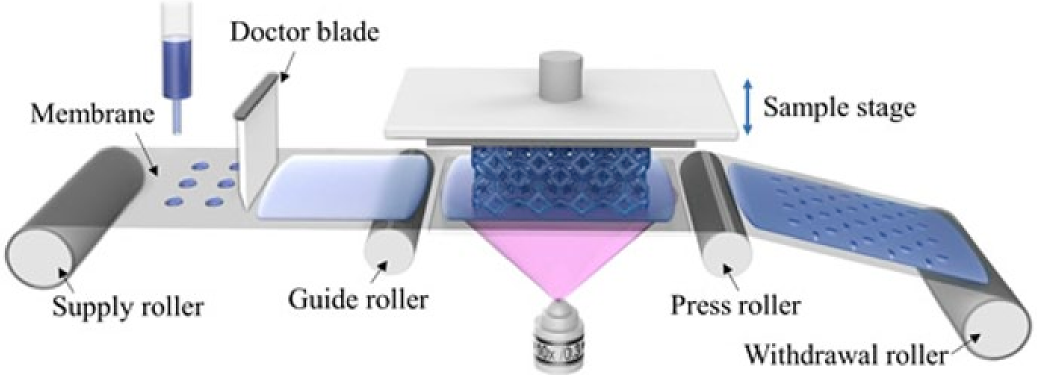
3D Sponge ~ 61% porous
typical pore widths from 10-50 μm



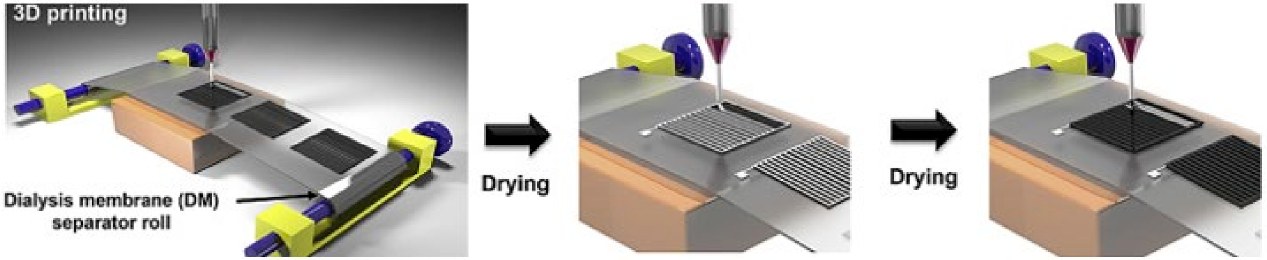
Energy Environ. Sci., 2014, 7, 117

Approaches towards: Integrating Advanced Manufacturing into Automatic Product Line

Digital light processing + roll-to-roll



Direct ink writing + roll-to-roll



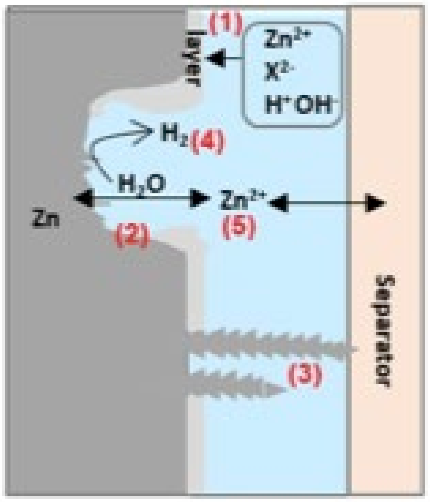
New low cost (aqueous) ink formulations

Wu, Xiumei, *et al*. Optics Express 29.14 (2021): 21833-21843.
Ovhal, Manoj Mayaji, *et al*. Cell Rep. Phys. Sci. 2.9 (2021).

w/LLNL

Highlight – ZHX, Electrolyte Development and Imaging (CINT)

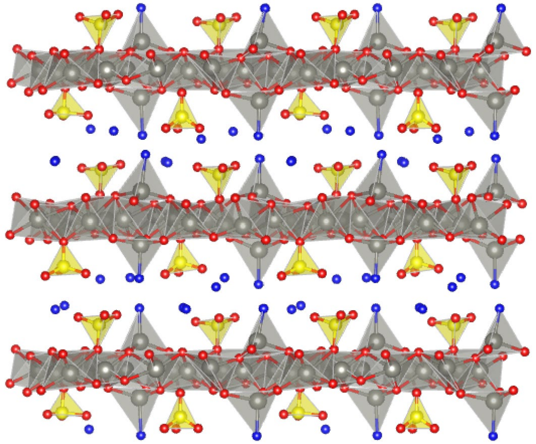
In mildly acidic batteries - underlying Li-ion mechanisms are commonly adopted to Zn-ion but supporting evidence is limited



Layer- $Zn_x(OH)_yX_z.nH_2O$

E.g. Reversibility and role of ZHX requires further study

$Zn_4(OH)_6SO_4$-xH_2O



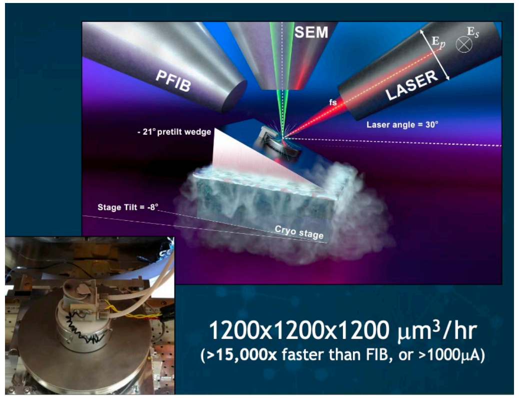
- ZHS Irreversible byproduct generated through HER ?

HER: $H_2O + e^- \rightarrow OH^- + ½ H_2$
ZHS Formation: $4\,Zn^{2+} + 6\,OH^- + SO_4^{2-} \rightarrow Zn_4(OH)_6SO_4$
Overall: $4\,Zn^{2+} + 6\,H_2O + SO_4^{2-} + 6\,e^- \rightarrow Zn_4(OH)_6SO_4 + 3\,H_2$

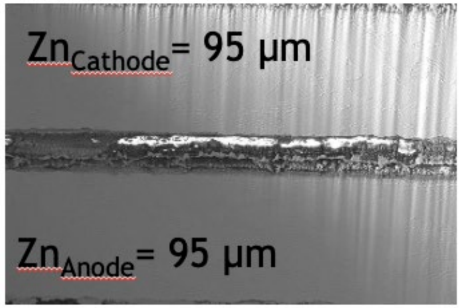
- Alternative reaction:

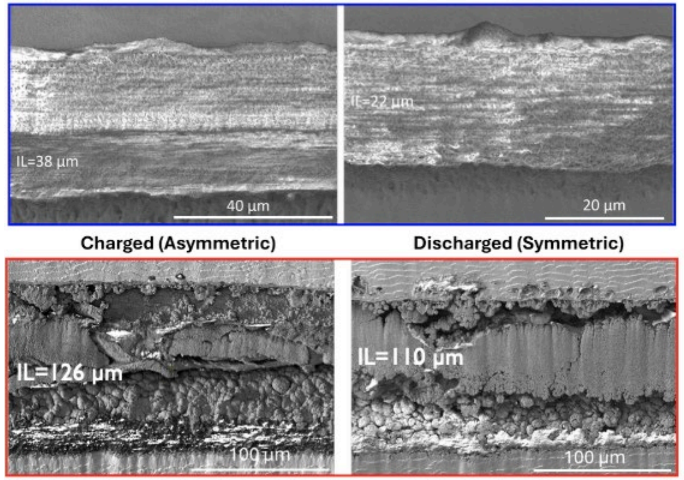
$$4\,Zn^{2+} + 6\,H_2O + SO_4^{2-} \rightarrow Zn_4(OH)_6SO_4 + 6\,H^+$$

Applying fs-LPFIB to evaluate ZHX



Pristine Zn/Zn cell





After 10 cycles, a layer of ZHA (Zn,C,O by EDS) is observed to reversibly form at the interface.

In contrast, a much thicker ZHS layer (Zn,S,O by EDS) forms in the sulfate cells and reversibility appears to be minimal.

Corrosion observed with ZnSO4.

PROJECT RESULTS –Zinc Batteries

FY25 Publications (2 published, *4 under review, 5 in preparation*)

1. K. Acharya, N Paudel, B. A. Magar, T. N. Lambert, I. Vasiliev “Ab Initio Studies of the Discharge Mechanism of CuO Cathodes Modified with Bi2O3 in Rechargeable Alkaline Zn/CuO Batteries” J. Electrochem. Soc. 2025, 172, 020504. DOI 10.1149/1945-7111/adad45.
2. G. G. Yadav, M. Sammy, J. Cho, M. N. Booth, M. Nyce, J. Huang, T. N. Lambert, D. E. Turney, X. Wei, S. Banerjee “Performance of Low-Cost Energy Dense Zinc|Manganese Di-oxide-Copper Cells of Commercial Scale” Batteries 2025 *manuscript accepted*.
3. D. Dutta, S. K. T.; D. E. Turney, C. D. Quilty, T. N. Lambert, R. J. Messinger, S. Banerjee “pH-Regulated Acetate-Based Aqueous Electrolyte and Its Impact on Zinc Utilization for Zinc Metal Batteries” J. Electrochem Soc. 2025 *manuscript under review*.
4. B. R. Wygant, C. Wright and T. N. Lambert “Optimization of Bi Additive Concentration and the Impact on the Performance of Secondary Zn/CuO Alkaline Batteries” J. Electrochem Soc. 2025 *manuscript under review*.
5. P. Yang, D. E. Turney, C. D. Quilty, T. N. Lambert, S. O’Brien, S. Banerjee “Unravelling the Cycling and Failure Mechanisms of Alkaline Rechargeable Calcium Zincate ($CaZn_2(OH)_6 \cdot 2H_2O$) Batteries, EES Batteries 2025 *manuscript to be submitted (OE Approved)*.
6. Y. Agilan, E. K. Zimmerer, B. R. Wygant, T. N. Lambert, J. W. Gallaway “Effect of Electrode Compression on the Rechargeability of Alkaline CuO Cathodes” 2025 *manuscript under review (by OE)*.
7. Y. Agilan, T. N. Lambert, J. W. Gallaway “A Review of Aqueous Cu-based battery electrodes” 2025 *manuscript in preparation*.
8. C. D. Quilty, I. I. Bezsonov, J. J. Huang, C. N. Wright, L. To, T. N. Lambert “Zinc-Ion Plating/Stripping and ZHX Formation/Consumption: Overlooked Complexities in Mildly Acidic Zinc Battery Research” 2025 *manuscript in preparation*.
9. Z. Chen, T. N. Lambert, N. Liu “Control of the perpendicular distribution of zinc in thick porous current collectors” 2025 *manuscript in preparation*.
10. Z. Chen, T. N. Lambert, N. Liu “Towards Rechargeable All-Manganese Aqueous Batteries” 2025 *manuscript in preparation*.
11. A. Frischknecht ““Diffusion of Hydrogen Gas and Ions in Poly(potassium acrylate)/KOH Solutions” 2025 *manuscript in preparation*.

Sandia National Laboratories | The City University of New York | NM State University | Northeastern University | GT

PROJECT RESULTS –Zinc Batteries

FY 25 Presentation Highlights (16 total = 9 invited and 7 contributed)

T. N. Lambert (speaker, Invited talk) A04-0496 – "Investigations into the Electrochemical Cycling of Zinc in Mildly Acidic Electrolytes" at ***The Electrochemical Society Meeting***, Montreal, Canada 2025.

J. W. Gallaway (speaker, Invited talk) " Li-Ion and Na-Ion Batteries using Layered MnO_2 Cathodes with Pillaring Bi Cations" Electrolytes & Interphases in Sustainable Battery Technology, ***The American Chemical Society Fall Meeting***, Denver CO, Aug 2024.

TN Lambert (SNL), J. Galloway (NU) with David Reed, Xiaolin Li (PNNL) – **Co-chaired** "A04 - Separators for Zn Batteries" and "A04 - Large Scale Zn Batteries" sessions at ECS Montreal Canada.

Amalie Frischknecht, **Co-organizer and session chair**, "Transport Phenomena in Polymers for Energy Applications", an invited session at the 2025 APS Global Physics Summit, Anaheim, California, March 19, 2025.

Sandia National Laboratories | CINT | Pacific Northwest NATIONAL LABORATORY | CUNY The City University of New York | Northeastern University

FY 25 Patents

1. *Dutta, D.; Turney, D.; Lambert, T. N.; Banerjee, S. "ACETATE-BASED ELECTROLYTE FOR USE IN HIGH-VOLTAGE ZINC AQUEOUS BATTERIES" Provisional Patent filed.*

Sandia National Laboratories | CUNY The City University of New York

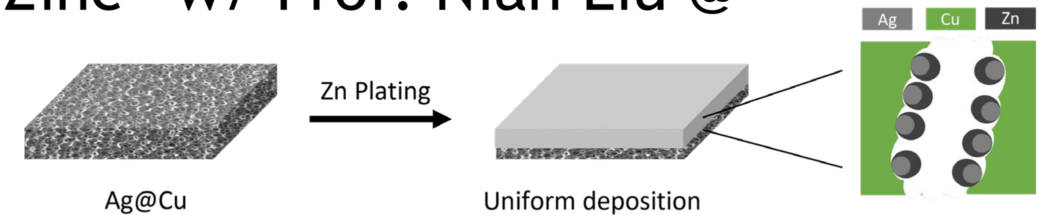
PROJECT RESULTS –Zinc Batteries

Two CINT Proposals selected:

1. “Enabling High Areal Capacity 3-Dimensional Zinc” w/ Prof. Nian Liu @ Georgia Tech

   Goal: *Gain better understanding of zinc electroplating in 3-dimensional, anodes in aqueous electrolytes*

   Hypothesis: *Preferential deposition on Ag will utilize the Cu foam surface area and prevent dendrites and shorts leading to higher volumetric capacities*

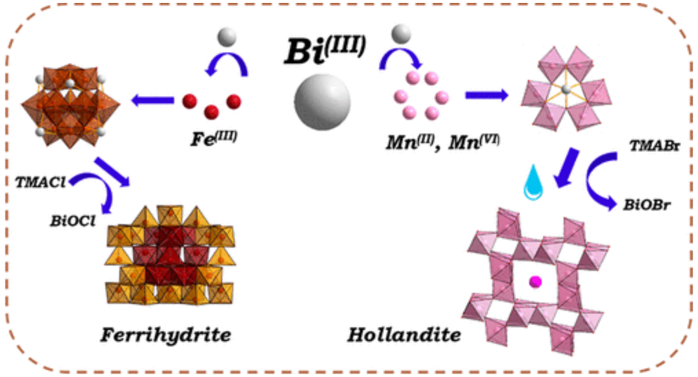


Nova 600 Nanolab FIB/SEM at CINT/SNL
Cryo-laser PFIB at SNL/CINT

2. “Identification of Bismuth Supramolecular Clusters in Aqueous Conversion Cathodes” w/ Prof. Josh Gallaway @ Northeastern

   Goal: *Understand the role of Bi in enabling MnO_2 and CuO-based cathodes in alkaline batteries.*

   Hypothesis: *Rechargeability is enabled by the formation of supramolecular compounds based on Bi and Mn, and/or Bi and Cu.*



Bi-metastable cluster scheme
Adapted from Amiri *et al.* (2020).

Xenocs Xeuss 3.0 SAXS capability at CINT-LANL

PROJECT CONTACTS

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Sandia Team

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Lauren To

Cy Fujimoto

Amalie Frischknecht

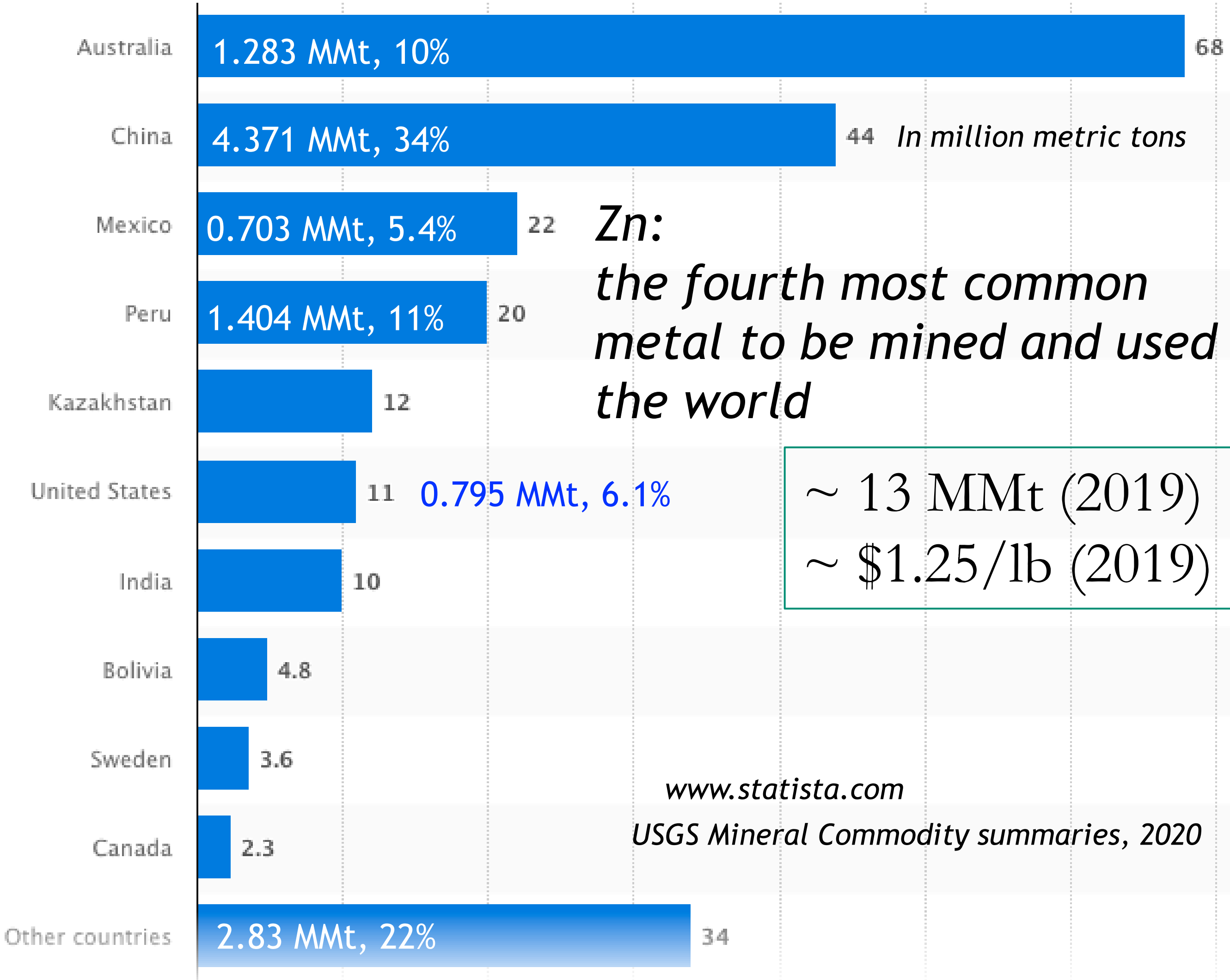
ACKNOWLEDGEMENTS

This material is based upon work supported by the U.S. Department of Energy, Office of Electricity (OE), Energy Storage Division

Thank you

A case for Zn-based batteries

(2019 Production) 2020 Global Reserves of Zinc



Zn: the fourth most common metal to be mined and used in the world

~ 13 MMt (2019)
~ $1.25/lb (2019)

www.statista.com

USGS Mineral Commodity summaries, 2020

https://www.usgs.gov/centers/nmic/zinc-statistics-and-information

Zn

1º Alkaline Zn/MnO_2 as an exemplar

Wikipedia, user Aney, 2005

- Existing supply chain
- > 10B units Zn/MnO_2 produced (2019)
- $7.5B global market (2019)
- Affordable ~ $20/kWh
- Aqueous w/long shelf life
- EPA certified for disposal (safe)
- High achievable energy density
  - Zn/MnO_2 ~ 400 Wh/L
  - Zn/Air ~ 1400 Wh/L
  - Zn/Ni ~ 300 Wh/L
  - Zn/CuO ~ 400 Wh/L

Challenge for Zn Batteries = high cycle life at high utilization

Rechargeable Zn-based Batteries

- Low-cost, high-energy density, safety, and global availability have made Zn-based batteries attractive for more than 220 years!
- *Diverse* Zn-batteries offer a range of properties to meet growing demand across varied applications:

✓ Grid stability and resilience

✓ Backup power (assurance for data centers, telecom, etc.)

✓ AI/ML

✓ Resource Extraction (High Power)

✓ Behind-the-meter applications for residential and commercial applications (Lower energy cost, power quality, etc.)

$Zn\text{-}MnO_2$

URBAN ELECTRIC POWER

1 MWh UEP alkaline battery backup system for the San Diego Supercomputer Center (CA).

ZĒLOS

Zn-Ni

ZincFive

ZAF Energy Systems

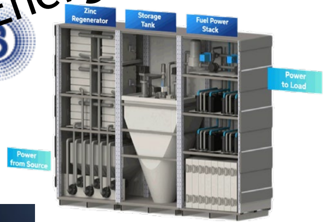
Æsir Technologies, Inc.

ENZINC

Zn-Air

Abound Energy Inc

ZINC8

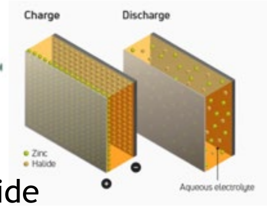


ZAF Energy Systems

e-zinc

Zn-Br

eos



35 MWh EOS Zn-Br system planned to provide 10-hour storage for microgrid with Indian Energy (CA).

redflow

Zn-Br flow battery installation

Zn-ion

SALIENT ENERGY

coulomb TECHNOLOGY

enerpoly

Rechargeable Zn-based Batteries

- Low-cost, high-energy density, safety, and global availability have made Zn-based batteries attractive for more than 220 years!

Zn-MnO_2

URBAN ELECTRIC POWER

1 MWh UEP alkaline battery backup system for the San Diego Supercomputer Center (CA).

ZĒLOS

$Zn + 2MnO_2 + 2H_2O \rightarrow ZnO + 2MnOOH$
OCV = 1.61 V per cell; Operating V = 1 – 1.5V
Practical Specific Energy Density
~ 90 – 150 Wh/kg
135 – 450 Wh/L

Zn-Ni

ZincFive

ZAF Energy Systems

Æsir Technologies, Inc.

ENZINC

$Zn + 2NiOOH + 2H_2O \rightarrow Zn(OH)_2 + Ni(OH)_2$
OCV per cell = 1.73V; Operating V = 1.2-1.6V
Practical Specific Energy Density
~ 70 – 150 Wh/kg
200 – 450 Wh/L

Zn-Air

Abound Energy Inc

ZAF Energy Systems

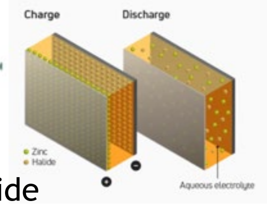
e-zinc

$Zn + 1/2O_2 \rightarrow ZnO$
OCV = 1.65 V per cell; Operating V = 0.9 – 1.4V
Practical Specific Energy Density
~ 100 – 400 Wh/kg
135 – 1000 Wh/L

High utilization of capacity
Bidirectional oxygen electrocatalysis remain challenging

Zn-Br

eos



35 MWh EOS Zn-Br system planned to provide 10 h storage for microgrid with Indian Energy (CA).

redflow

Zn-Br flow battery installation

$Zn + Br_2 \rightarrow ZnBr_2$
OCV = 1.85 V per cell; Operating V = 1 – 1.8V
Practical Specific Energy Density
~ 65 – 75 Wh/kg
60 – 70 Wh/L

Zn-ion

SALIENT ENERGY

coulomb TECHNOLOGY

IMPRINT ENERGY

Printed Energy

enerpoly

$Zn + MO_x \rightarrow ZnMO_x$
OCV = 1.60 V per cell; Operating V = 1 – 1.5V
Practical Specific Energy Density
~ 80 – 150 Wh/kg
200 – 450 Wh/L

Values from: Josef Daniel-Ivad, International Zinc Association, WVU Zinc Battery Supply Chain Workshop Presentation, April 2024

Sandia's Zn-Based Grid Storage Batteries Portfolio Team

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Molecular Modeling of Electrolytes for Earth-Abundant Batteries

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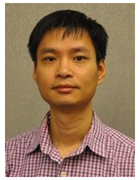

Cheng Zhu

Scalable manufacturing of 3D structured zinc anodes for zinc metal batteries

Tony Van Buuren