Zinc|Manganese Dioxide Batteries for Long Duration Energy Storage (LDES) Systems

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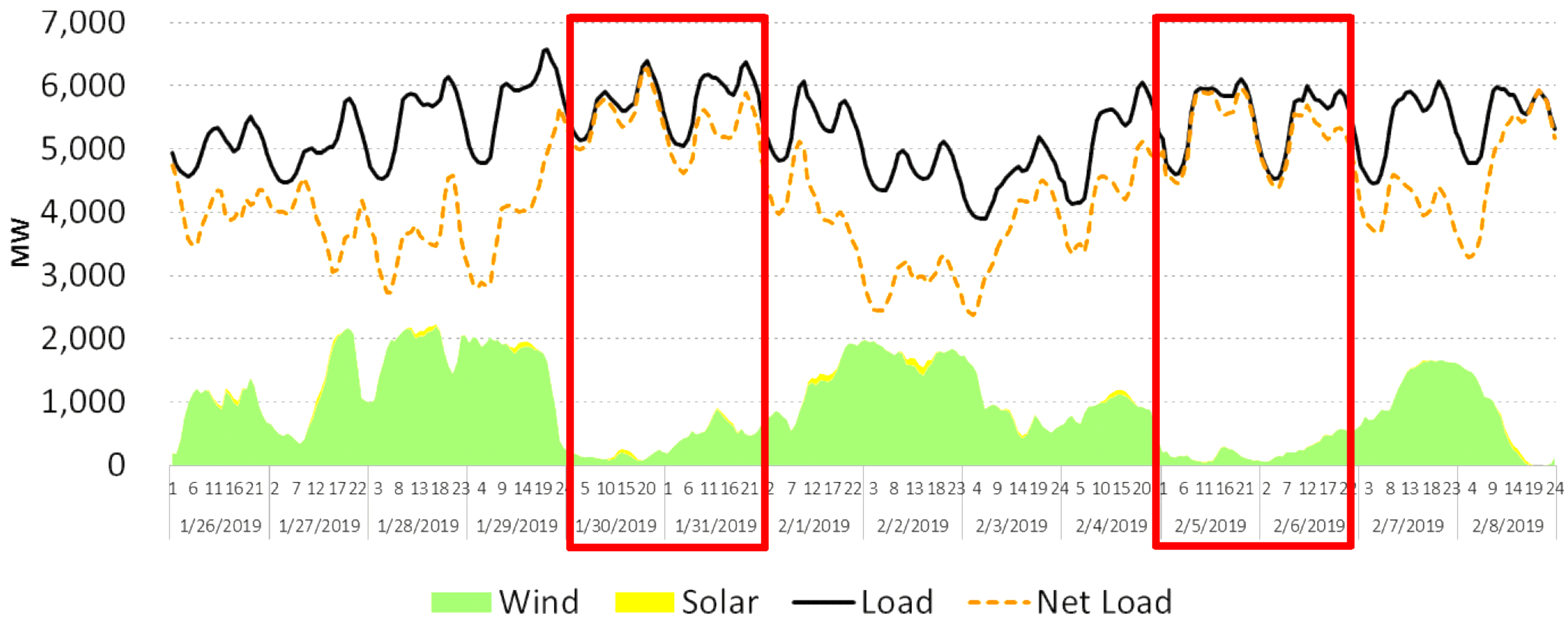
DOE Peer Review Meeting

Need of Viable Solutions for LDES

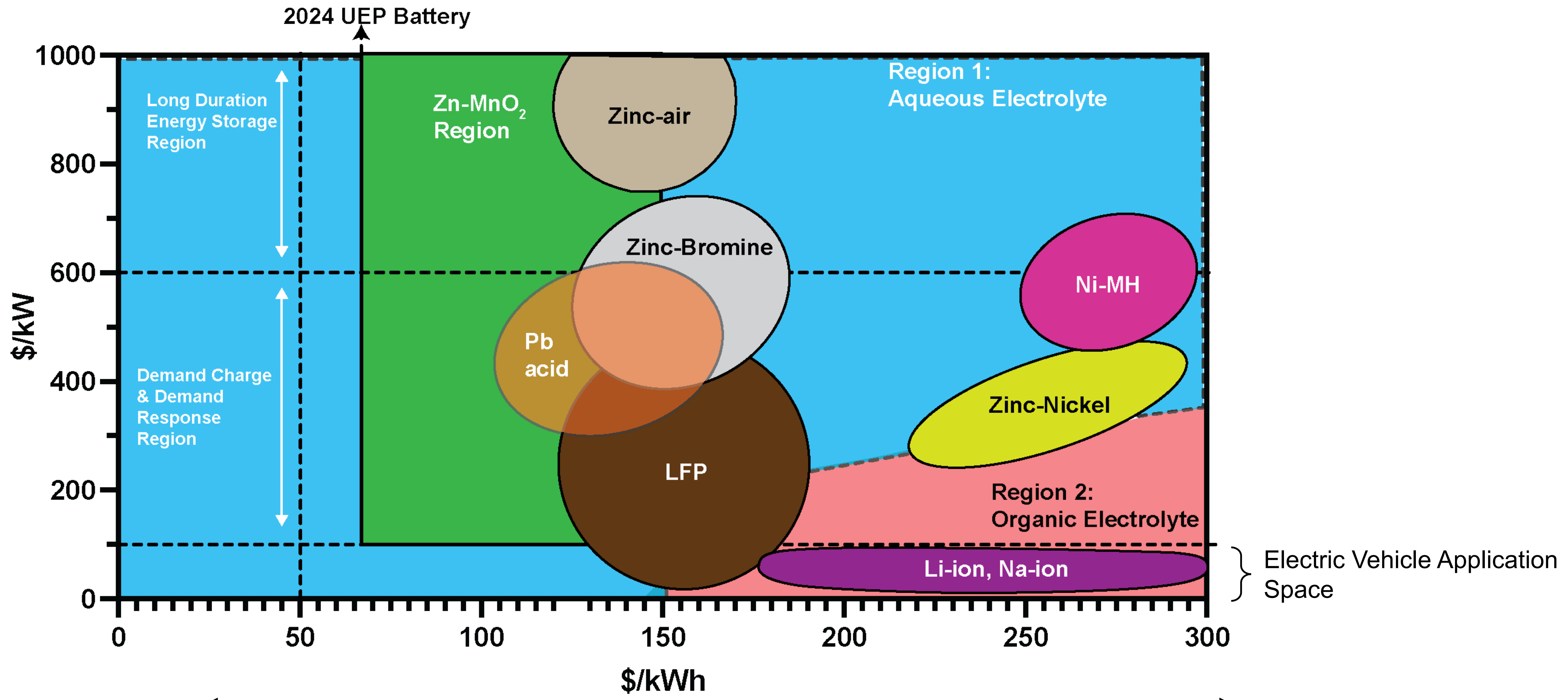
Key Takeaway: ***For greater penetration of renewables into the grid we need storage solutions >10+ hours***



Credit: XCEL Energy

Applications Space Overview

Key Takeaway: ***Aqueous batteries can serve the need for LDES solutions***

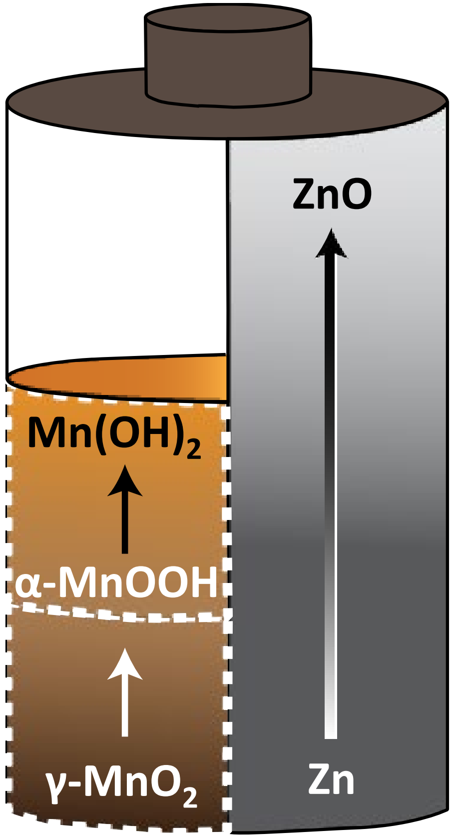


Active material contribution is higher. Bobbin-type cell designs are a good solution

Inactive contribution like current collectors to the overall cost dominates

Introduction to the Zinc|Manganese Dioxide Chemistry

Key Takeaway: ***Chemistry has the potential to be a high energy density battery coupled with its safe and non-toxic properties***



Chemical Precipitation

$$Zn(OH)_4^{2-} \longrightarrow ZnO + 2OH^- + H_2O$$

Dissolution-Precipitation

$$MnOOH + H_2O + e^- \longrightarrow Mn(OH)_2 + OH^-$$

Dissolution-Precipitation

$$Zn + 4OH^- \longrightarrow Zn(OH)_4^{2-} + 2e^-$$

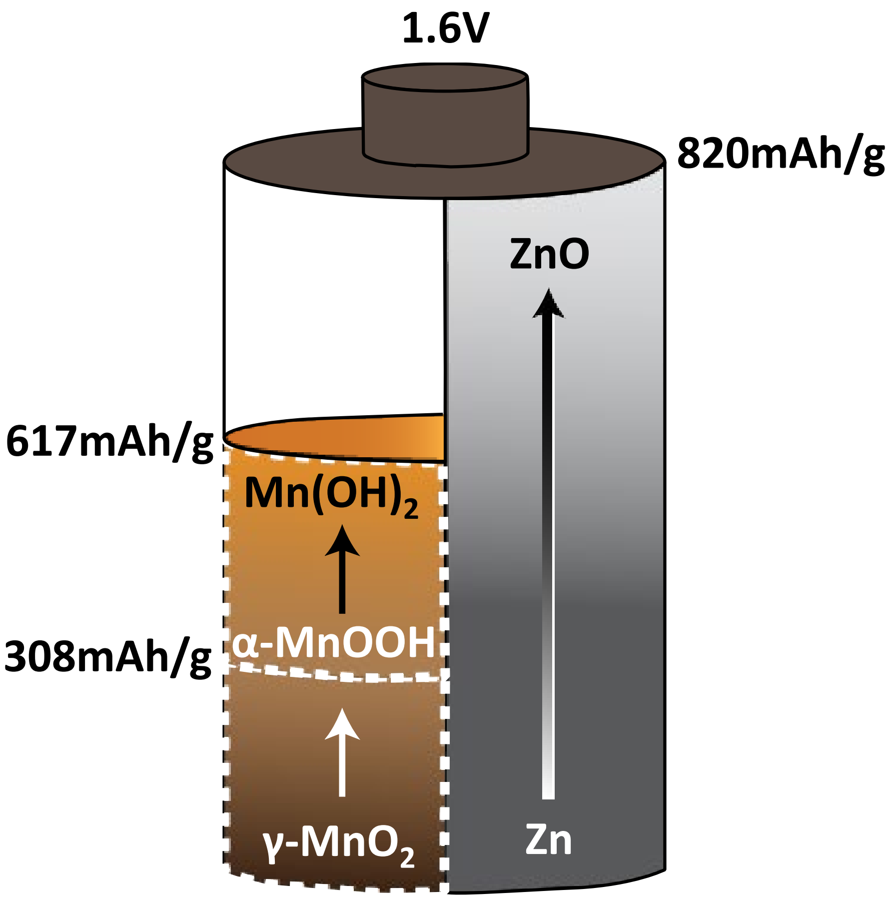
$$MnO_2 + H_2O + e^- \longrightarrow MnOOH + OH^-$$

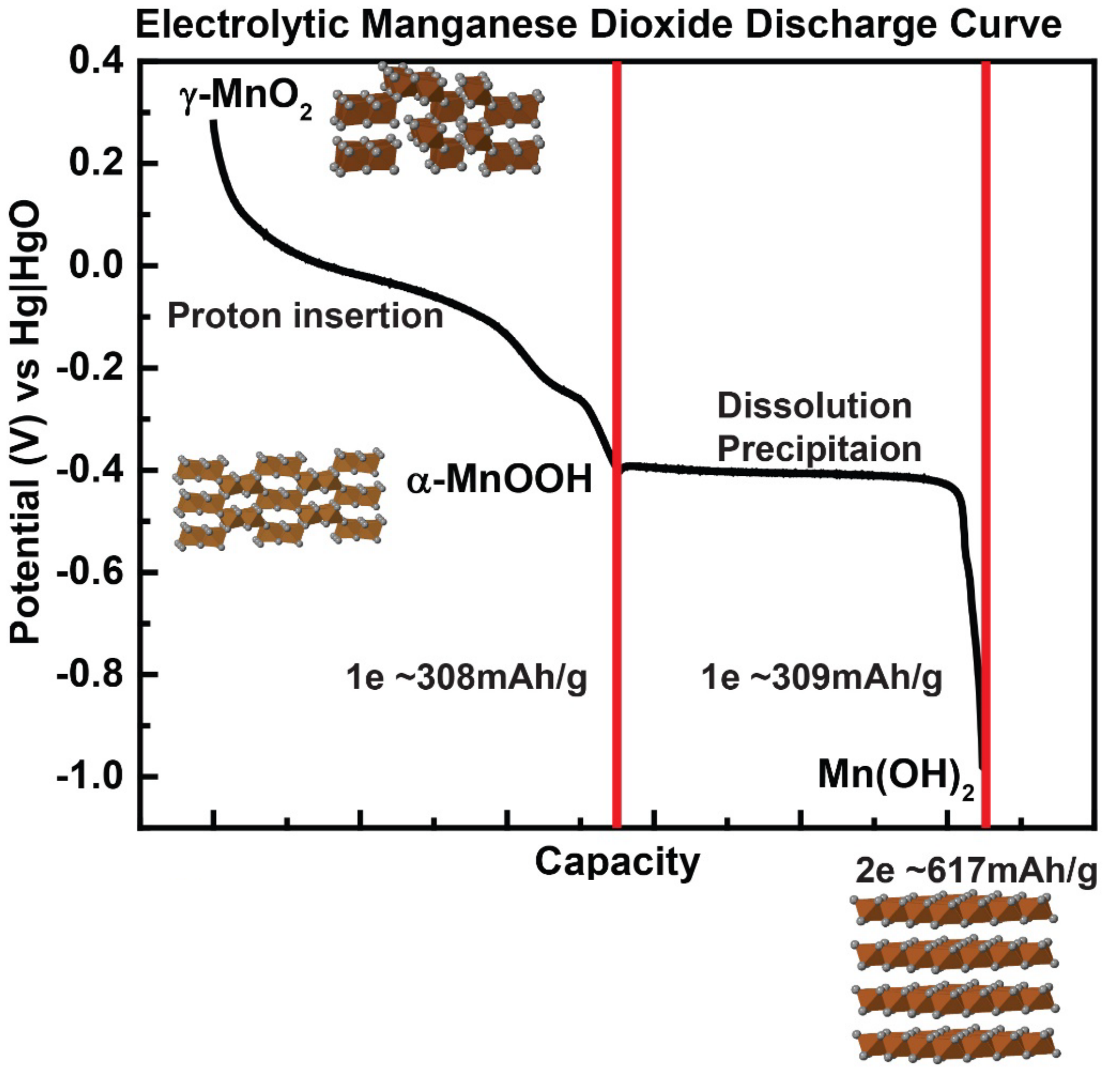
Proton Insertion

Solid state Reaction

Introduction to the Zinc|Manganese Dioxide Chemistry

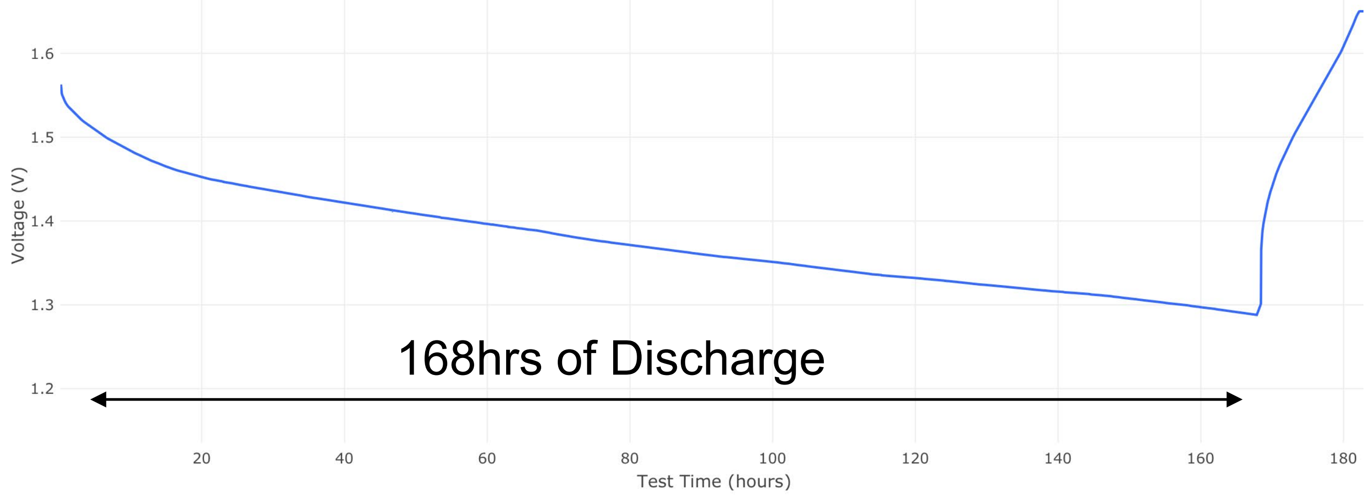
Key Takeaway: ***Reversibility is dictated by which electron is accessed in the MnO_2 discharge.***





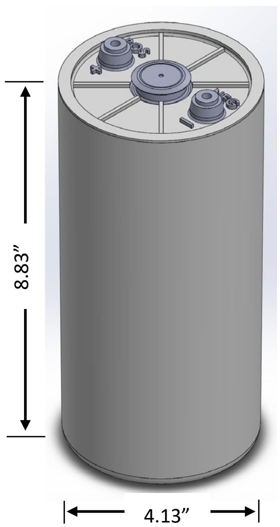
UEP Cells for LDES

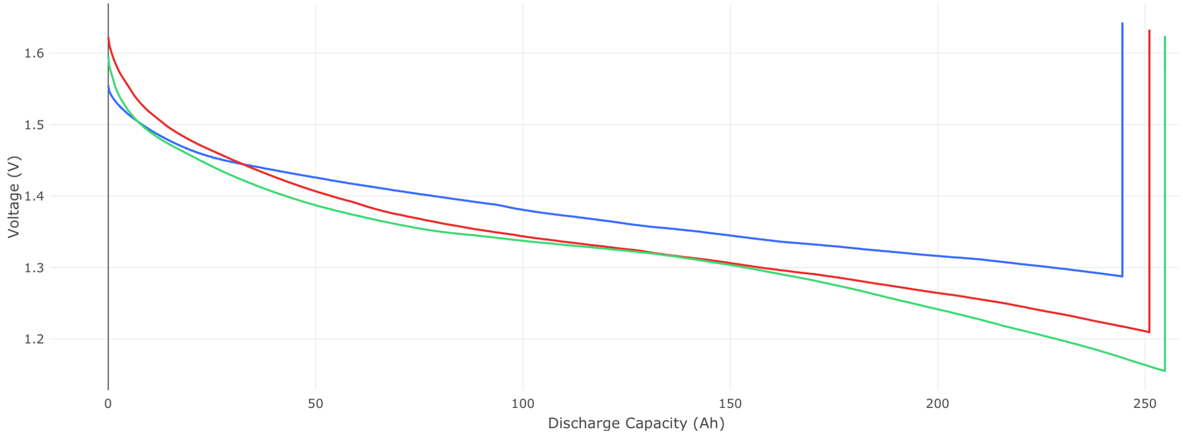
Key Takeaway: ***UEP cells can provide 1 week of discharge multiple times at high energy efficiency***

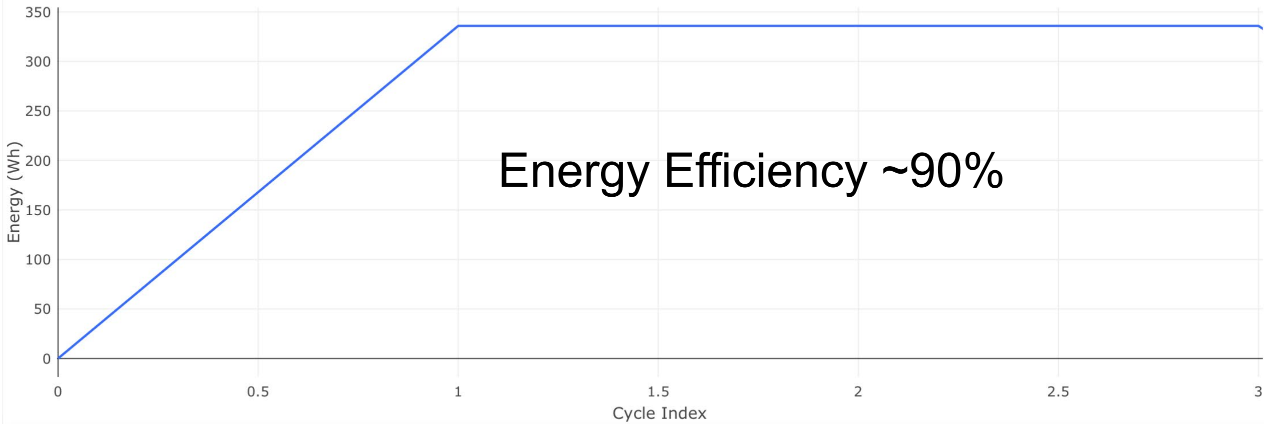


Cell charged in ~14hours

High-Energy Cell







Citation: UEP data

Comparison

Key Takeaway: ***Zn-anode batteries are versatile but cathode determines the viability for specific applications***

	UEP Current Generation $Zn\text{-}MnO_2$	EOS Zn-Br	Zinc8 Zn-air	E-Zn Zn-air	Zinc Five Zn-Ni	ZAF Zn-Ni
Self-Discharge	**0.01% per day**	1% per hour	N/A	N/A	0.1% per day	0.1% per day
Round Trip Efficiency	**80-90%**	70-80%	64%	40-50%	71-88%	85%
System Energy Density (Wh/L)	**>100**	11	N/A	N/A	34	N/A

Targeted for intraday storage (EOS)

Targeted for LDES (Zinc8, E-Zn)

Targeted for Short Duration Storage (Zinc Five, ZAF)

Citation: Publicly available data

Safety Study of the UEP's Battery

URBAN ELECTRIC POWER

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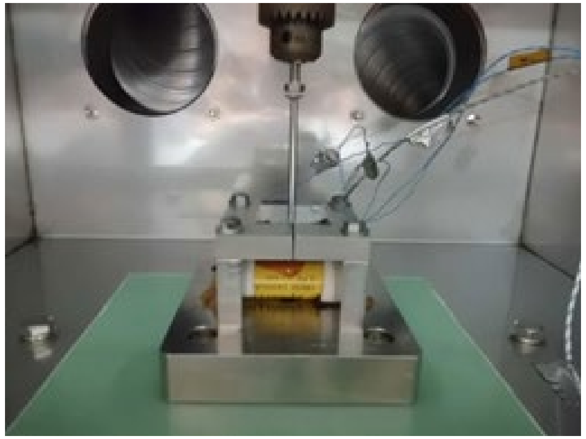
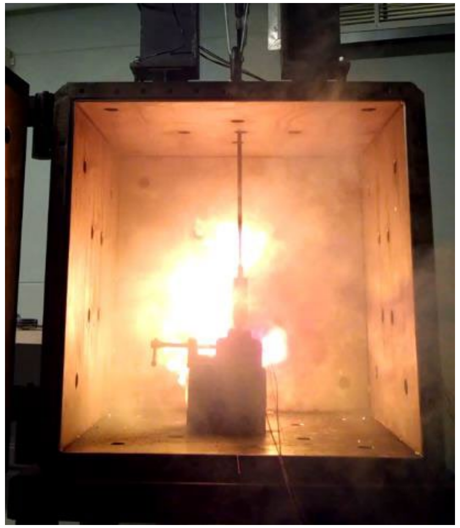
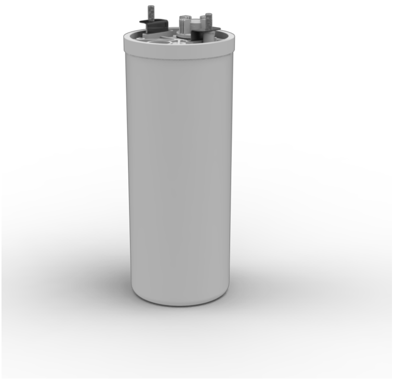
Nail Penetration Test



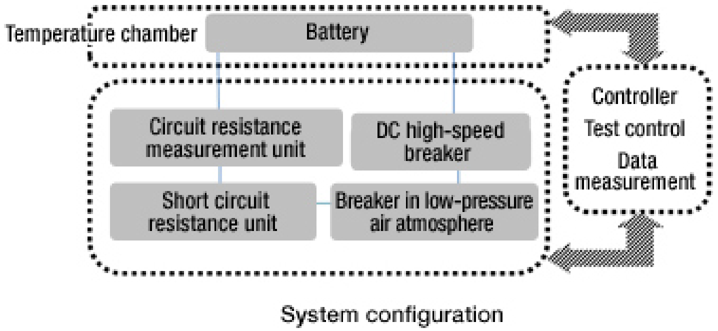
Heat Exposure Test



Overcharge Test



Short Circuit Test



Key Takeaway: *UEP cells tested by 3rd party for safety evaluation*

Citation: UEP data

Nail Penetration Test

URBAN ELECTRIC POWER

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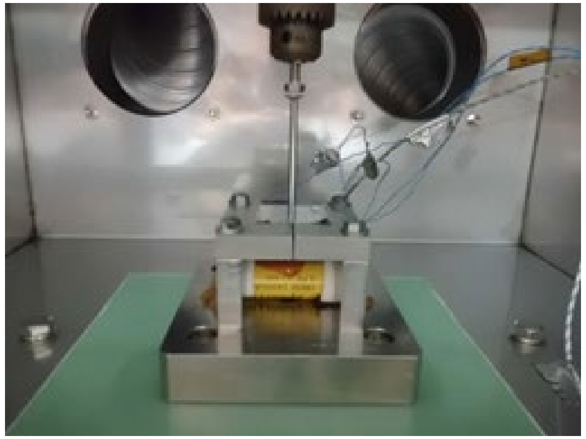
Key Takeaway: ***Cells did not result heat generation and spillage issues. Passed the nail penetration test***

Nail Penetration Test



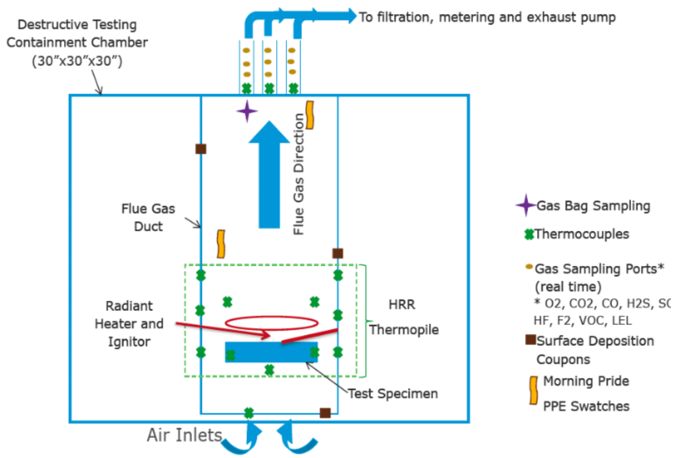
- *Low internal resistance of the cell*
- *Low chemical spill risk because of the general toughness of the cell*
- *Low likelihood of adverse chemical reaction*

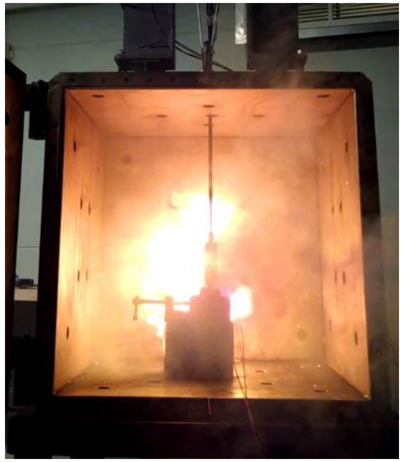
Citation: UEP data

Heat Exposure Test

Key Takeaway: ***Cells did not result in thermal runaway reaction and did not catch on fire. Passed heat exposure test***

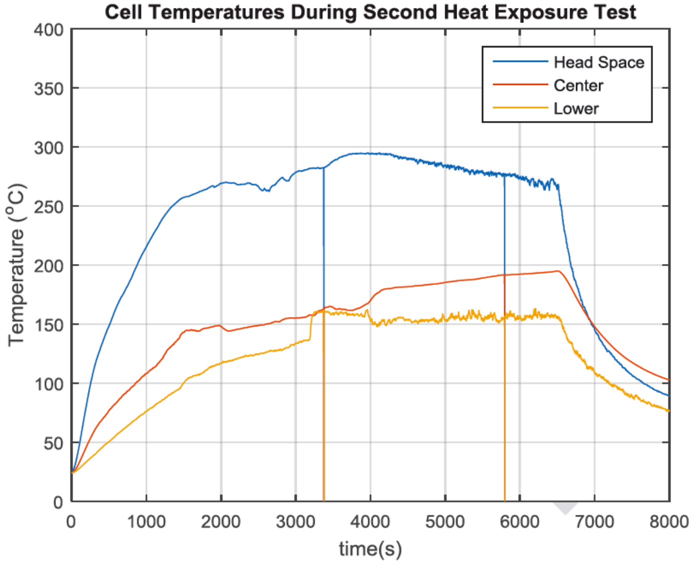
Experimental Design



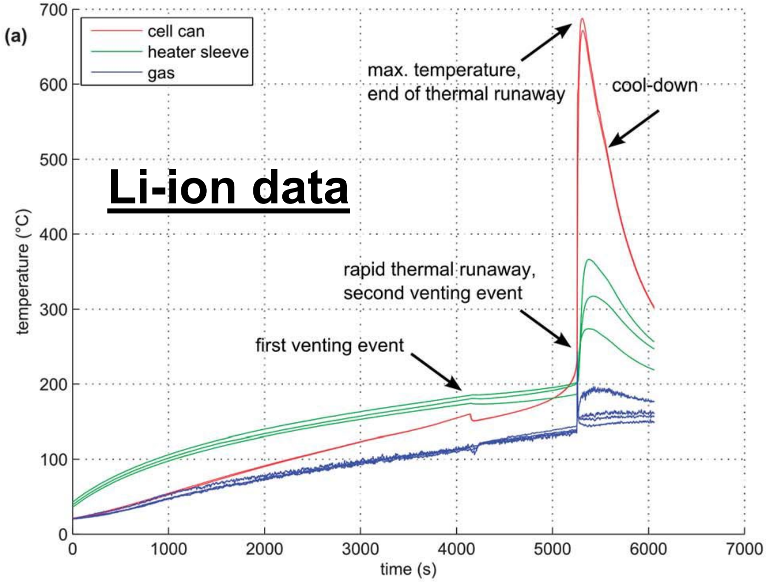


Thermal Runaway Comparison with Lithium-ion

Melted Down Cell Following Heat Exposure Test, No Fire!



Cell Temperatures During Second Heat Exposure Test

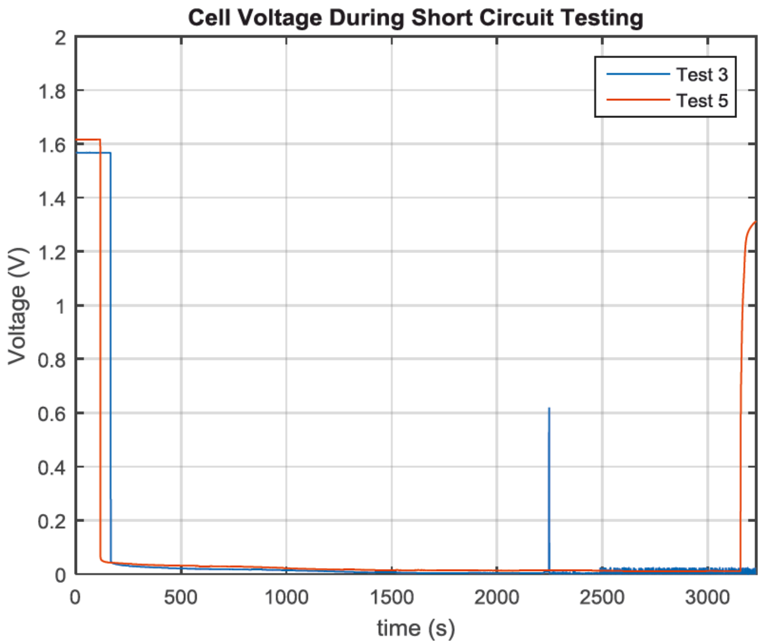


Citation: UEP data, RSC Advances, 2014,4,3633-3642

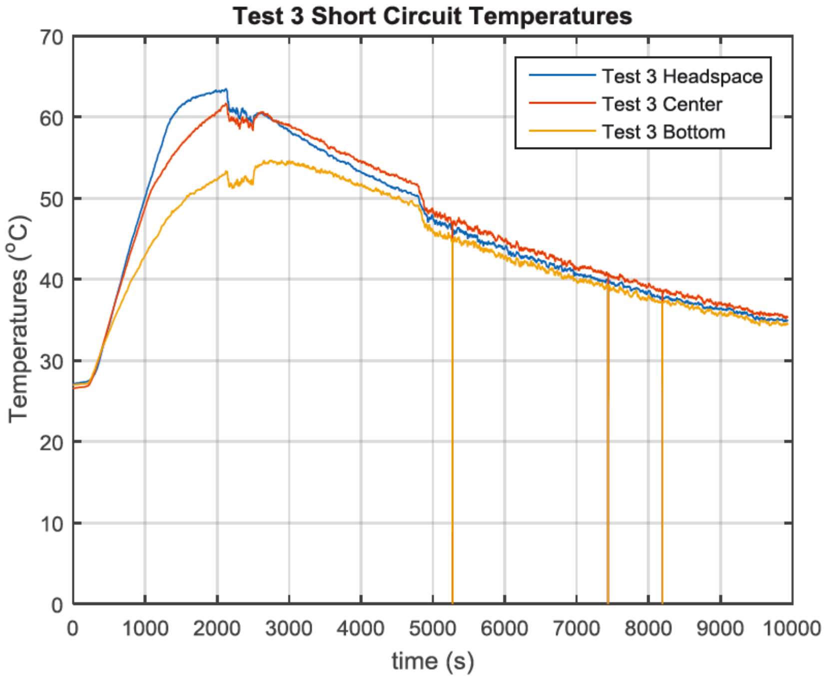
Short Circuit Test

<u>Key Takeaway:</u> The temperature increase in the cells was not high. They passed the short circuit test

<u>Shorting results in small Temperature rise but OCV is retained after short is released</u>



Voltage Response from Tests 3 and 5 During Short Circuit



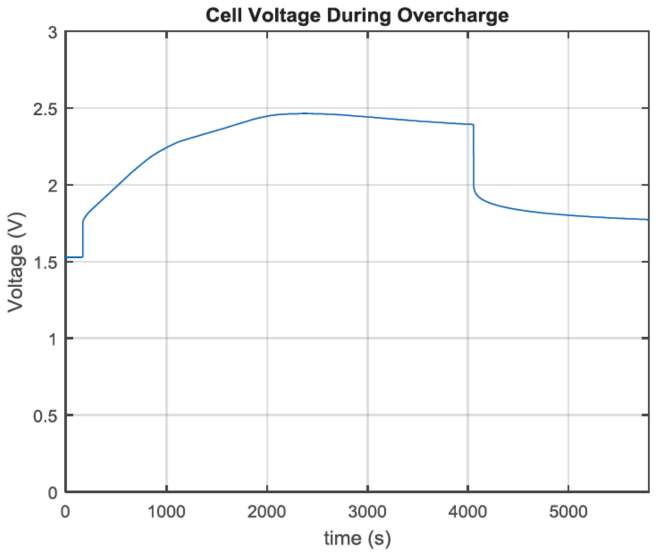
Short Circuit Test 3 Temperatures

Citation: UEP data

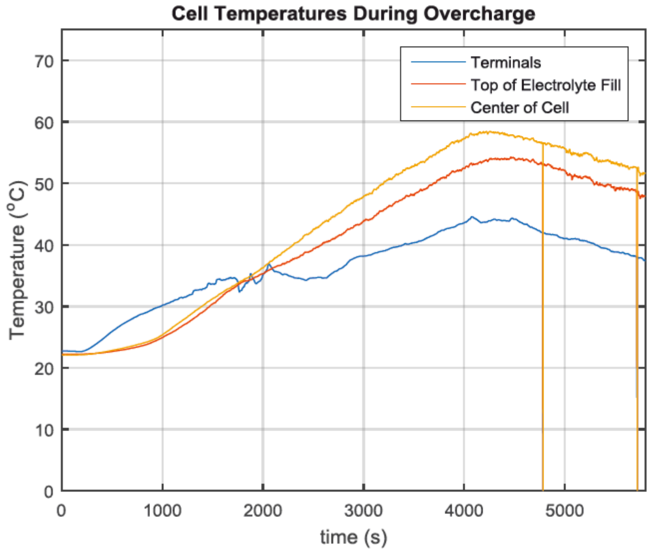
Overcharge

Key Takeaway: ***Overcharge of the cells results in mostly electrolyte breakdown with no safety related issues. Cells passed overcharge test***

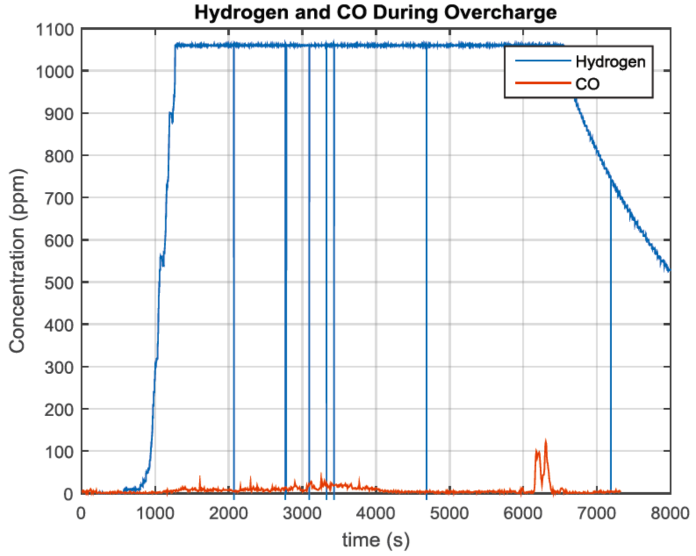
Overcharge results in slight temperature increase and H_2 formation



Cell Voltage During Overcharge Testing



Overcharge Cell Temperatures



Hydrogen and CO Gas Concentrations During Overcharge

Citation: UEP data

UEP LDES Projects

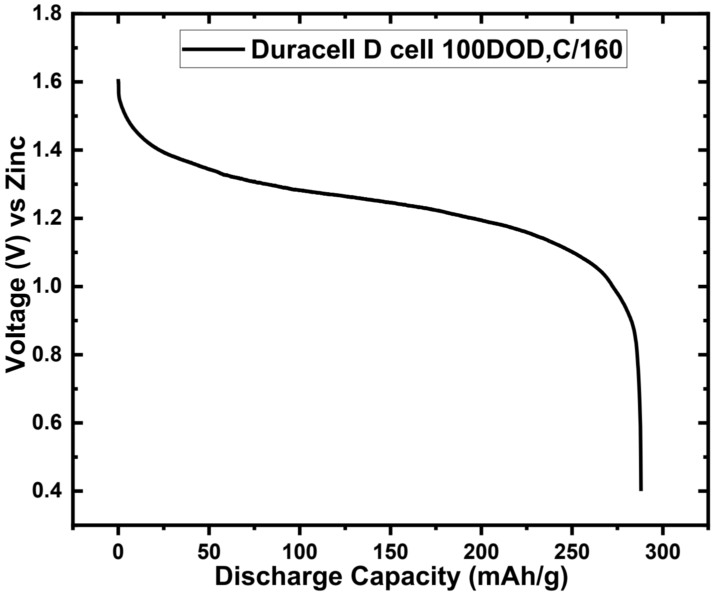
1. Project with NYSERDA
    1. Title: Deployment of Rechargeable Zinc Alkaline BESS for Long Duration Applications
    2. Size: 0.1MW/1MWh
    3. Collaboration: Hudson Valley Innovation Campus and EPRI
    4. Value: Provide power resilience to end users, reduce need for fossil fuel-based generators, allow for energy reduction through peak demand shaving, and support grid by participating in demand response events

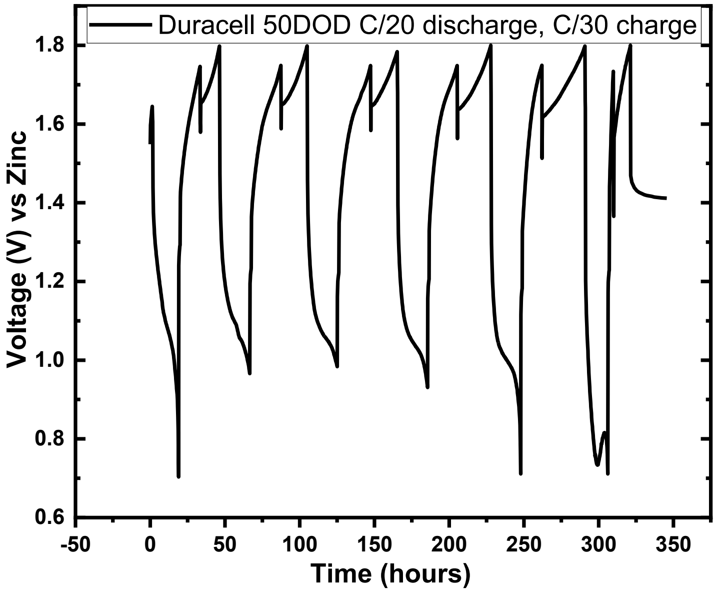
2. 2 other DOE Awards
    1. Title: Demonstration of Rechargeable Zinc Alkaline LDESS for Long Duration Applications in New York State
    2. Size: 2 Systems, Each is 0.3MW/3.6MWh
    3. Collaboration: NYPA and EPRI
    4. Value: Power backup, peak demand management and solar firming

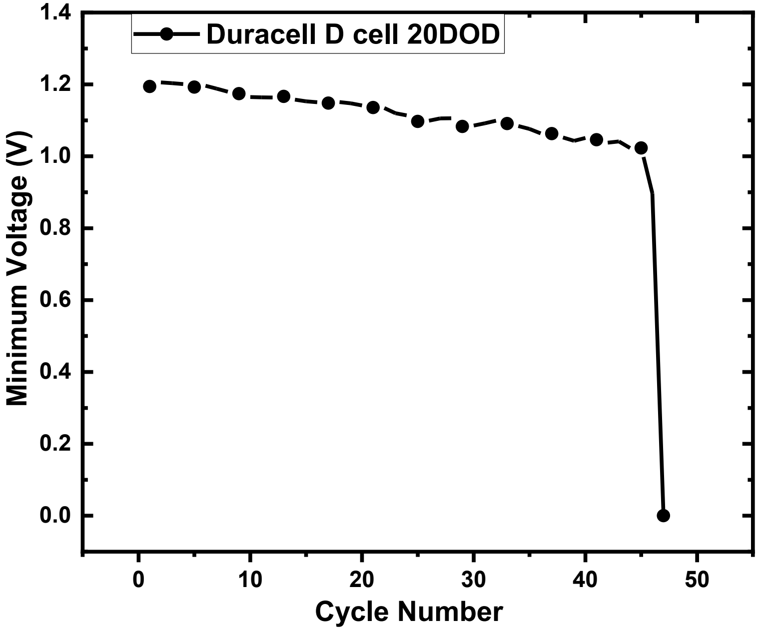
UEP Bobbin Project: Lowest Cost Cells

Assessing Commercial Cells

<u>Key Takeaway:</u> Bobbin-type cells are the lowest cost cells ($20-$40/kWh). But commercial cells suffer from rechargeability. Improvement in materials (electrode and electrolyte) property and internal cell design important for rechargeability.





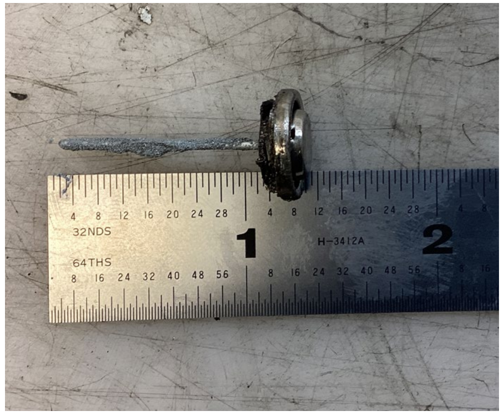


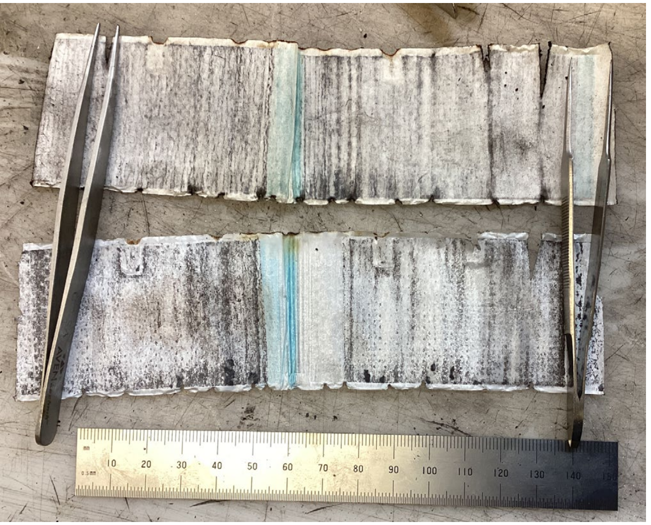
Funded by Sandia

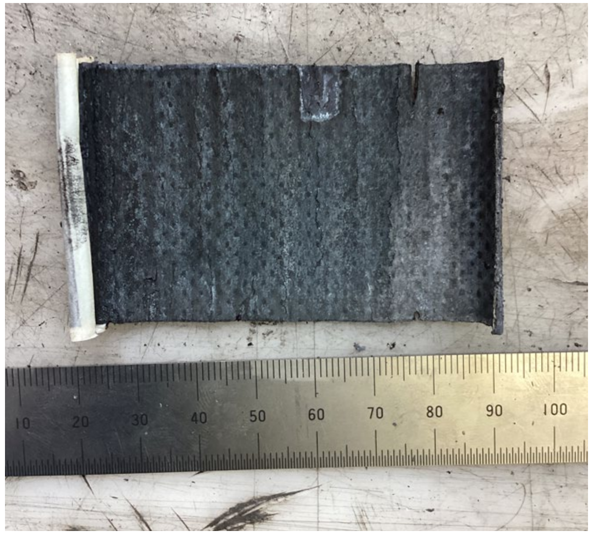
Manuscript in Preparation

UEP Bobbin Project

Dissection of Commercial Cells

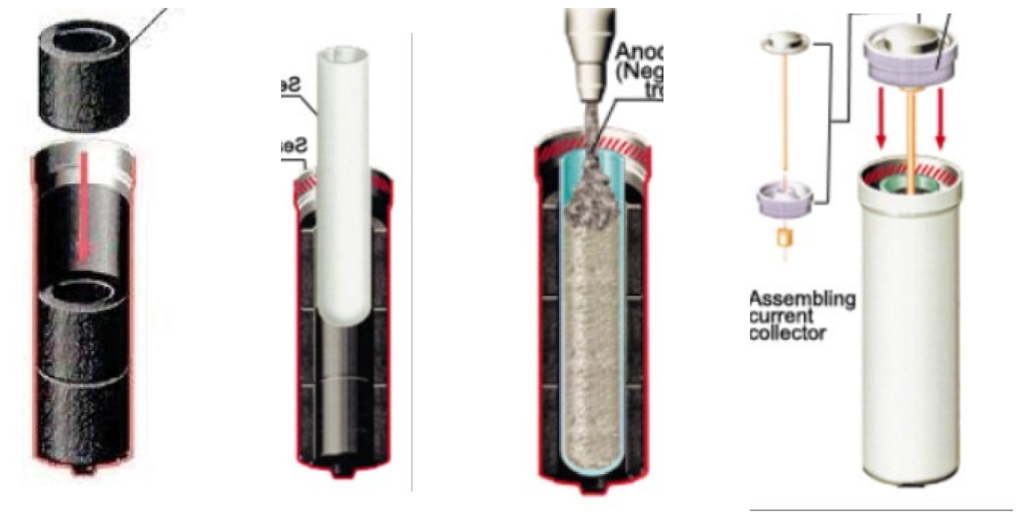






Assembly Process of UEP Cells

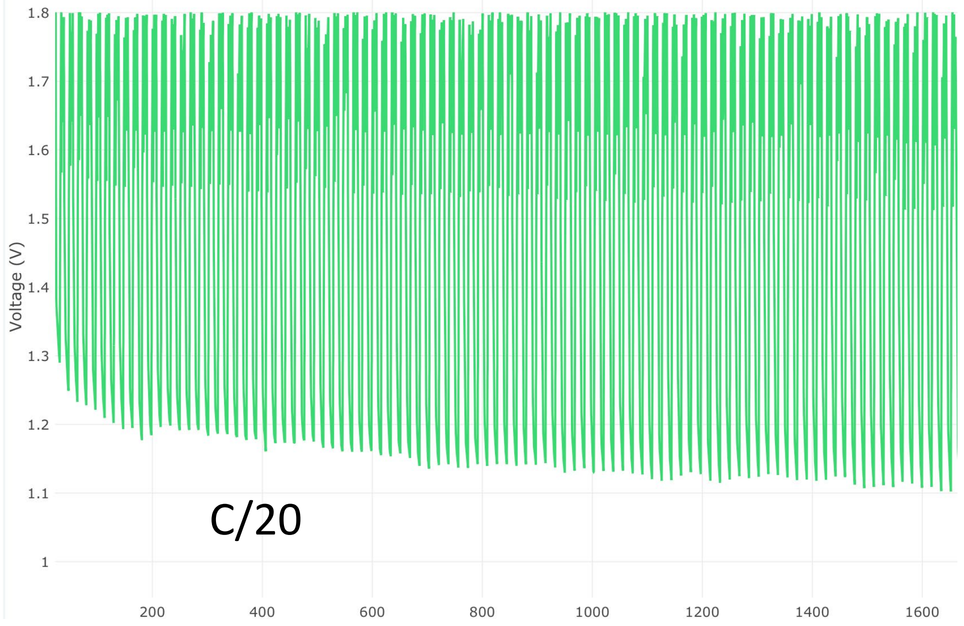
Step 1 Step 2 Step 3 Step 4

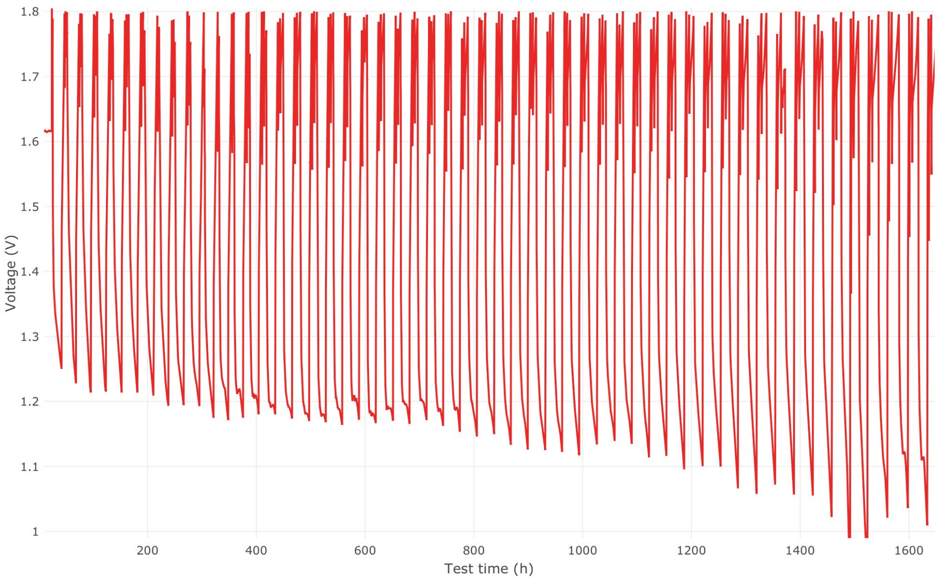


<u>Key Takeaway</u>: Learned about the bobbin cell design from various commercial cells. Learned the drawbacks in some designs and we have developed our own assembly process to make rechargeable bobbin cells

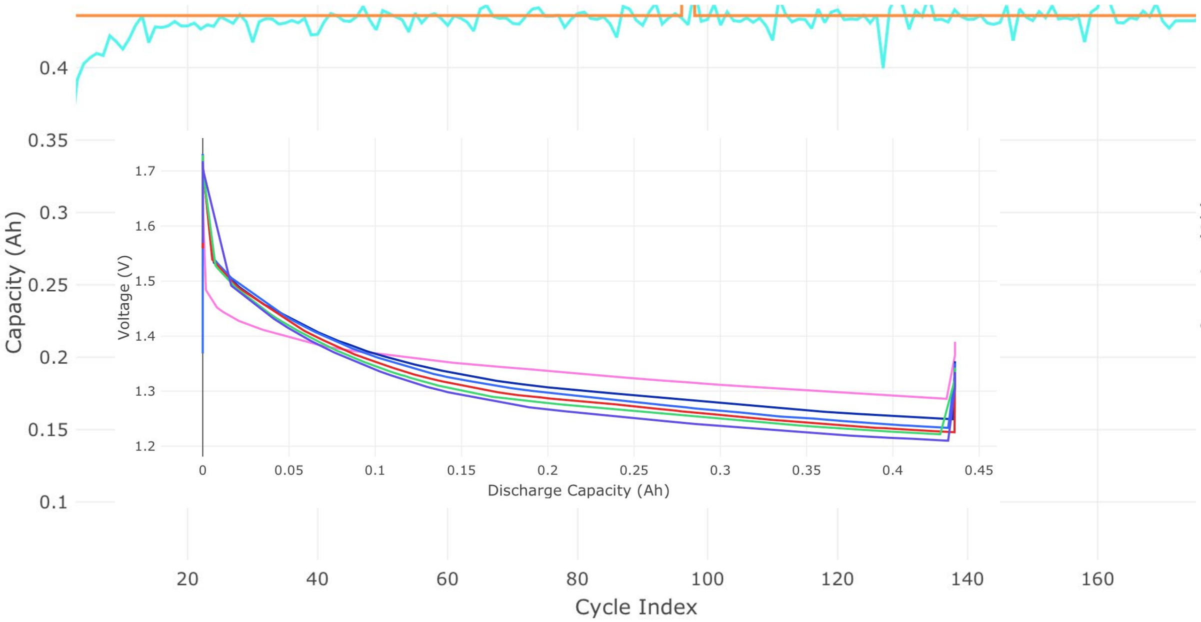
UEP Bobbin Project – Cycling Data

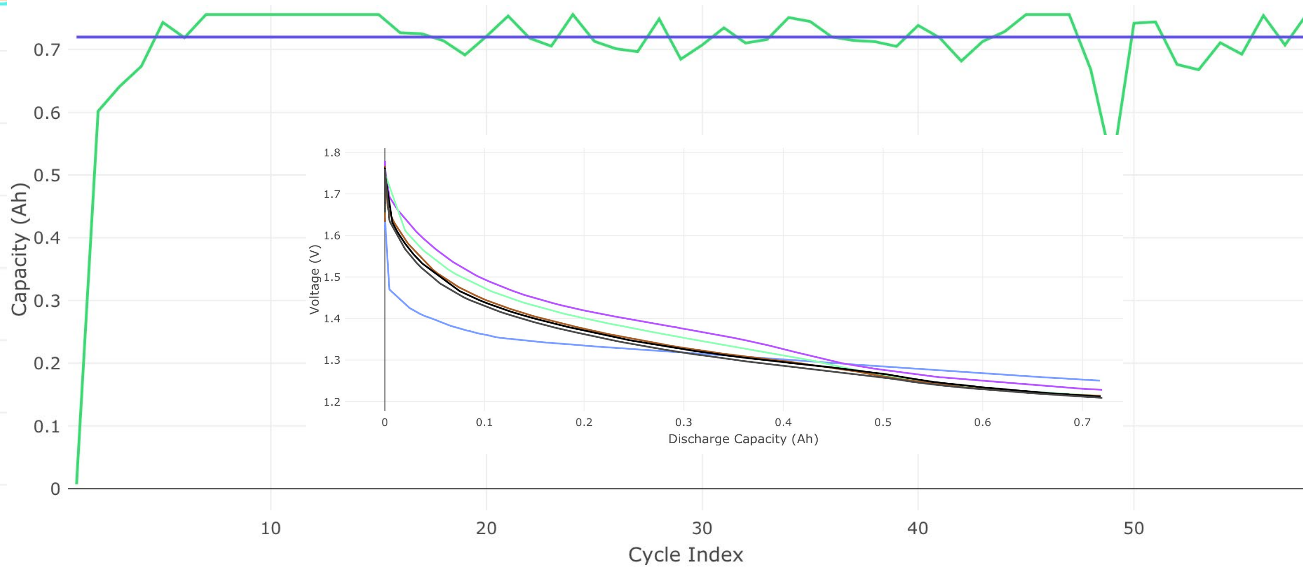
***Key Takeaway*:Achieved long cycle life cells at various C-rates.**





C/40

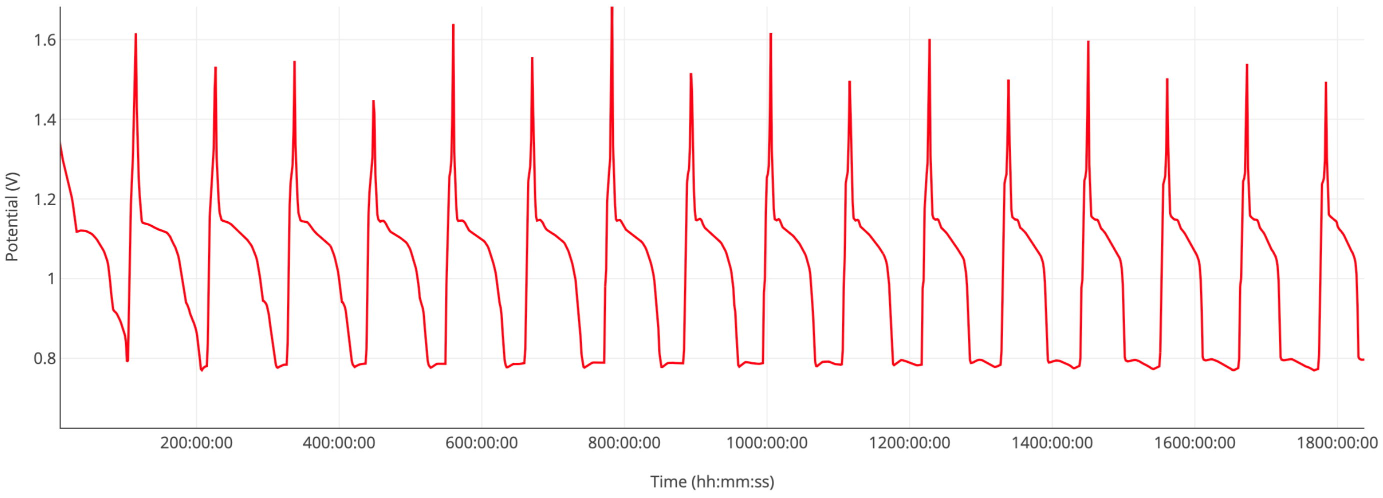


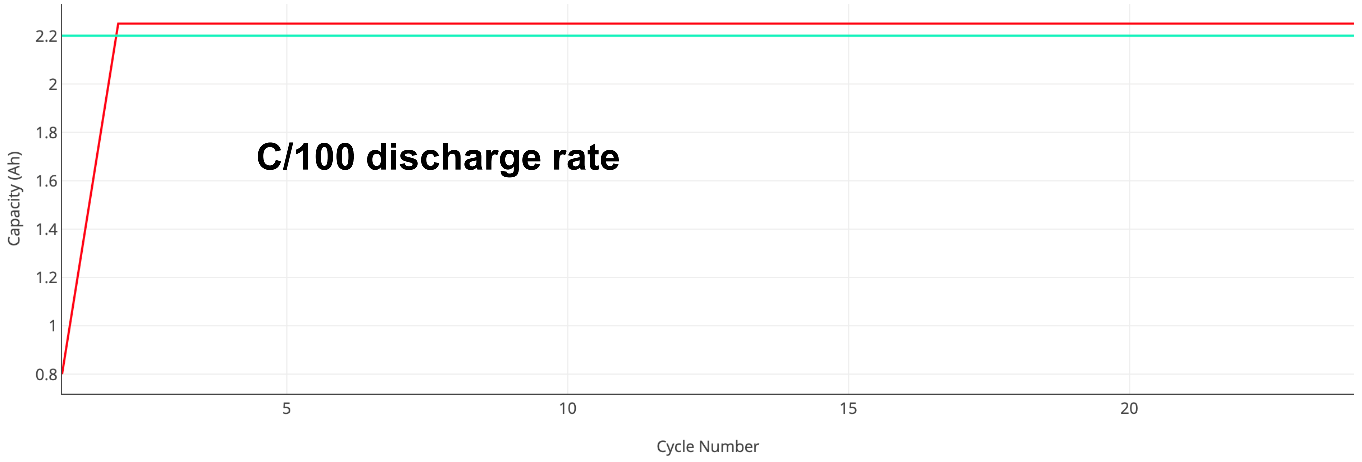


Funded by Sandia (PO #2190188)

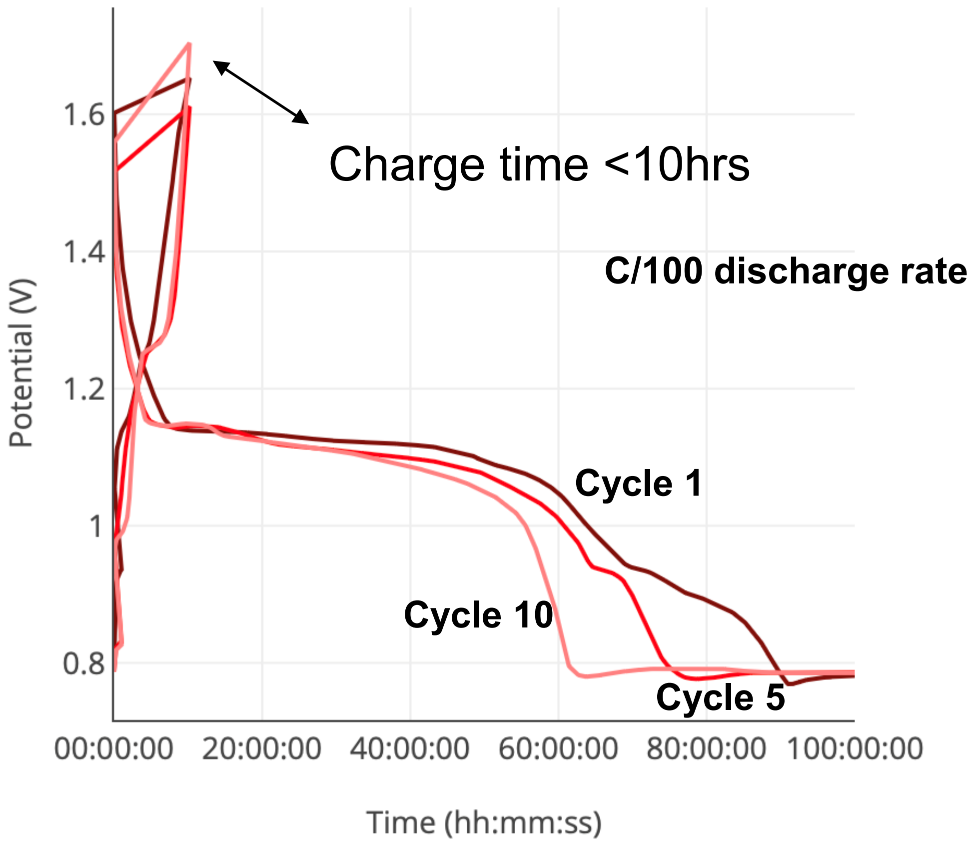
Citation: UEP Data

Next Generation Work - 2^{nd} Electron $Zn|MnO_2$





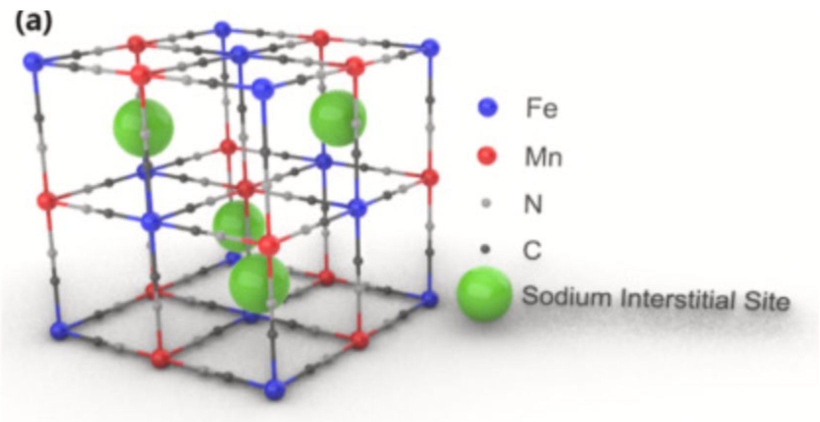
<u>Key Takeaway</u>:2^{nd} electron Zn|MnO2 cells can be used for LDES. Capable of fast charging and cycling multiple times at 100hrs of discharge

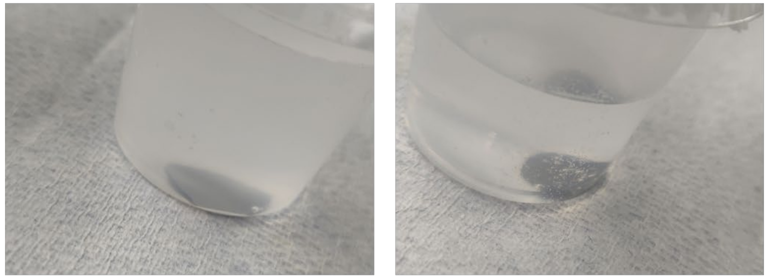


Collaboration with CCNY

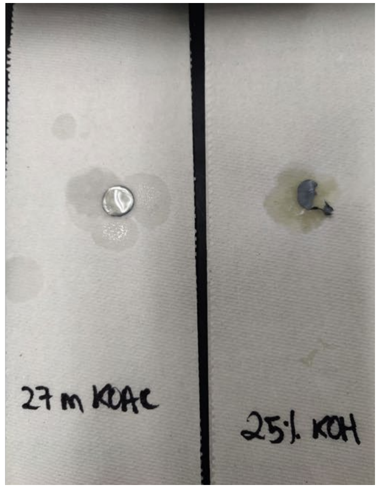
Check Jungsang Cho Poster

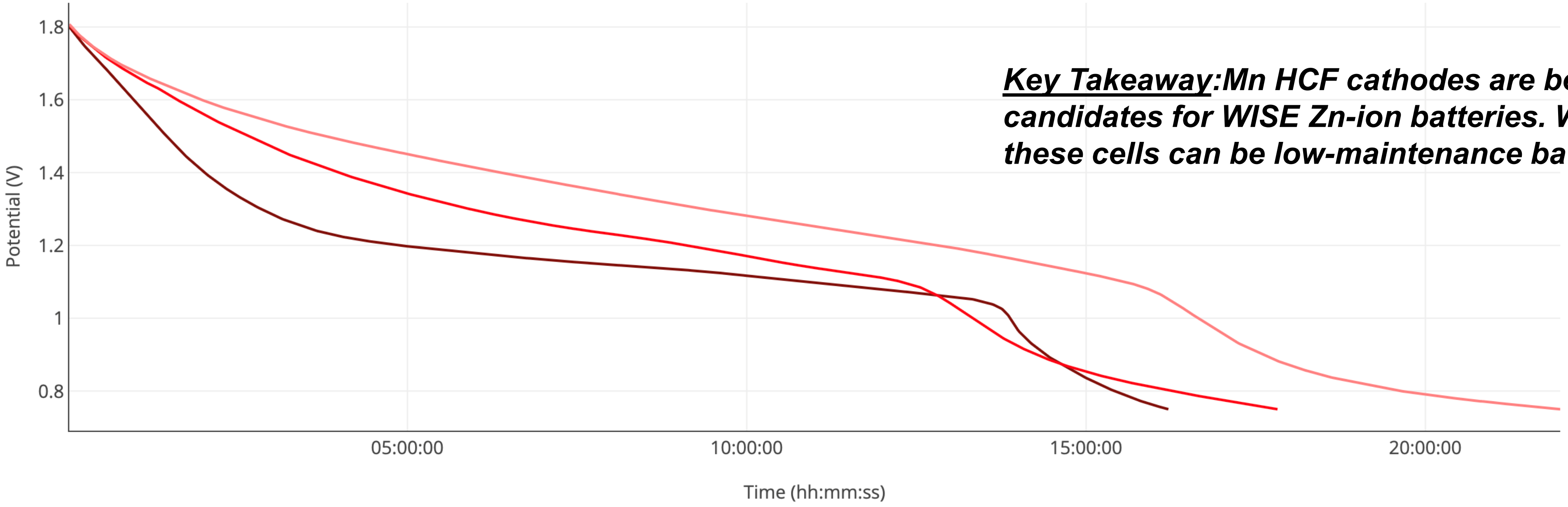
Next Generation Work – Water-in-salt (WISE) Zn-anode cells





Zinc foil placed in 27 m KOAc (left) and 25% KOH (right) after 1 month





<u>Key Takeaway</u>:Mn HCF cathodes are being studied as cathode candidates for WISE Zn-ion batteries. With H2 corrosion mitigated, these cells can be low-maintenance batteries for LDES

Collaboration with CCNY

Check Debayon Dutta Poster

Looking Ahead

- UEP will manufacture lowest cost Zn|MnO_2 cells
- There will be 3 installation projects for LDES
- Bobbin cells are ahead in their development curve. We will be testing modules made of bobbin cells for LDES application
- 2nd electron cells will be scaled to larger cells and made on the UEP production line for further LDES testing
- WISE-type Zn-anode batteries are early in development. Cathodes have been identified and are being tested for LDES.

Acknowledgements

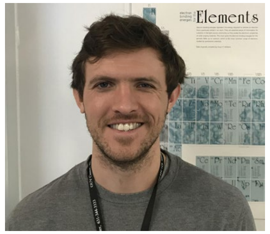
UEP Team

Sanjoy Banerjee

Jinchao Huang

Meir Weiner

Kristen Vitale



Brendan Hawkins

Sandia Team

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Sandia National Laboratories