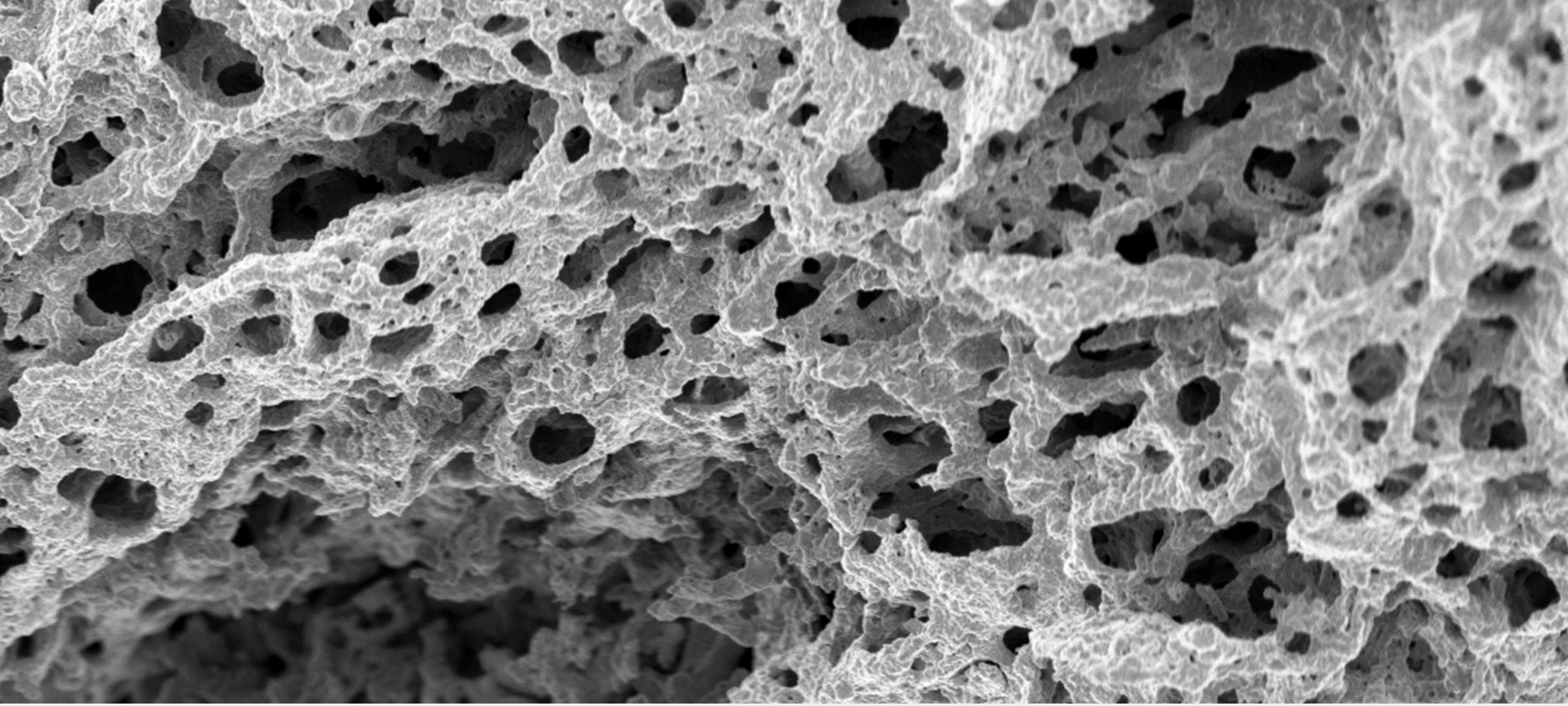


LITHIUM-ZINC: LITHIUM PERFORMANCE WITH THE COST AND SAFETY OF ZINC

ÆSIR TECHNOLOGIES BACKGROUND

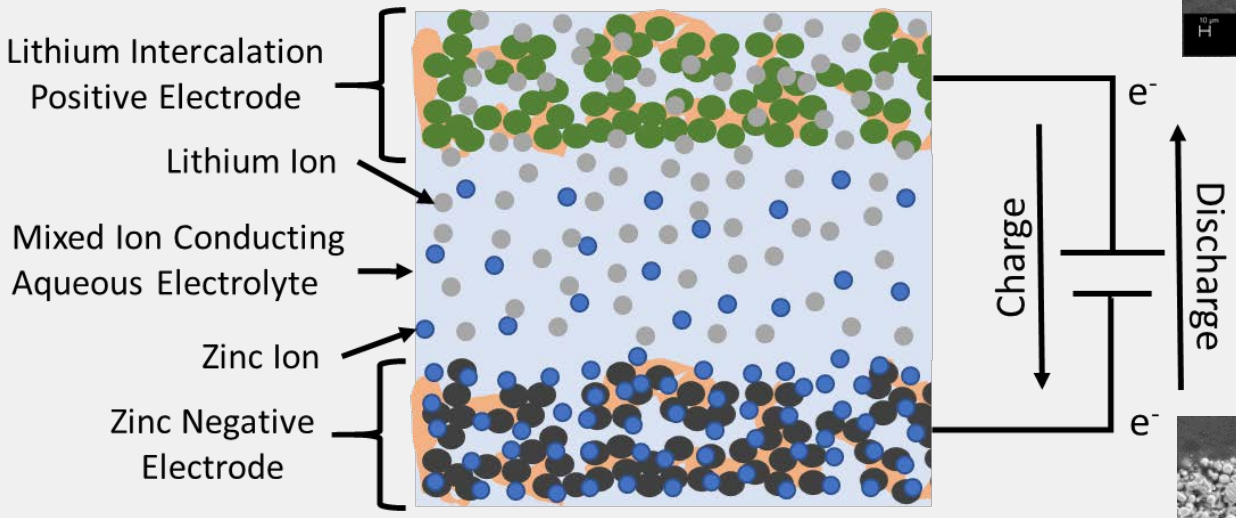
- Focused on the development of Zinc-based electrochemistries including:
  - Nickel-Zinc (Ni-Zn)
  - Lithium-Zinc (Li-Zn)
  - Zinc-Air (Zn-Air)
- Targeting Aerospace, Defense, Medical, and Critical Infrastructure
- 21 US patents and 37 total in process

Adam Weisenstein Ph.D.
Chief Technology Officer
Æsir Technologies &
Battery Grade Materials

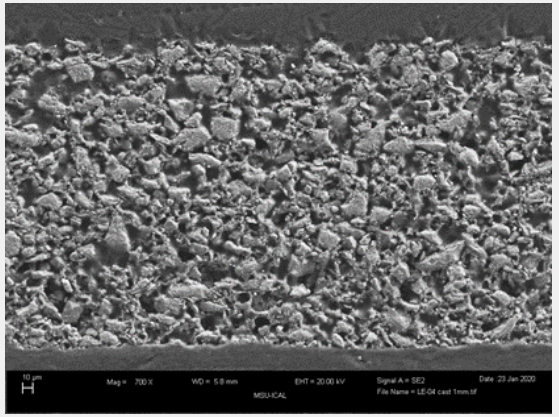
- 13+ years of materials and battery research experience with multiple scientific publications and 17 patents
- Lead author for the Nickel-Zinc chapter in Linden's Handbook of Batteries
- Expert in zinc battery chemistries and the development of novel materials from the R&D stage to production

WHAT IS LITHIUM-ZINC?

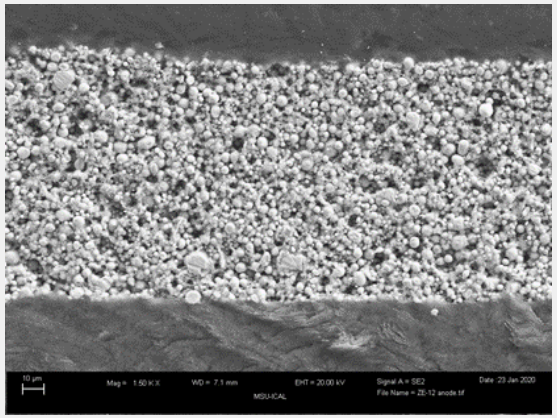
The Li-Zn battery consists of an intercalation electrode, a zinc electrode, and an acidic aqueous electrolyte containing both zinc and lithium ions.



A slightly acidic electrolyte allows for a simple anode design that delivers long life at low cost. The water-based electrolyte is also highly conductive and nonflammable.



$$Li_{1-x}Mn_2O_4 + xLi^+ + xe^- \leftrightarrow LiMn_2O_4$$



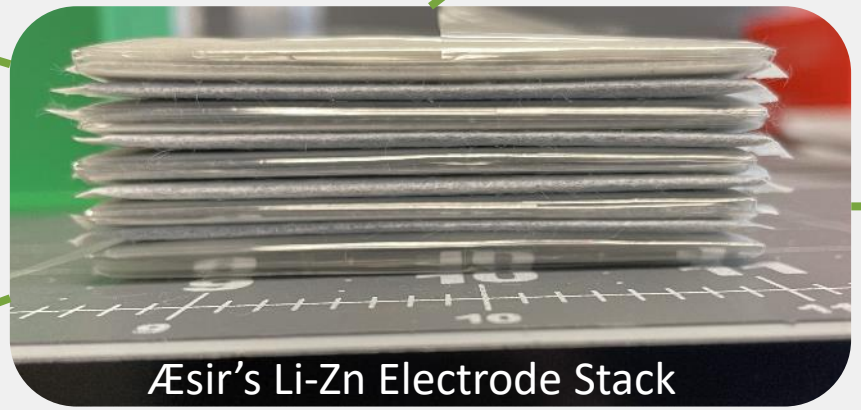
$$Zn \leftrightarrow Zn^{2+} + 2e^-$$

- National Science Foundation 24-month Phase II Cooperative agreement was granted in May 2022
- Goal of Phase II is to achieve a TRL of 5 in a scaled prototype

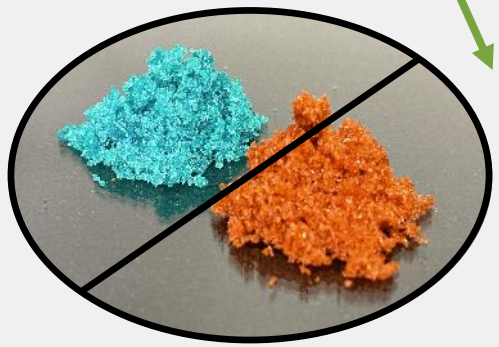
WHY LITHIUM-ZINC?

Non-flammable aqueous electrolyte

High energy density: 185 Wh/L based on 48 V 8D design


Æsir's Li-Zn Electrode Stack

Very inexpensive chemistry: estimated 35-45 $/kWh battery materials cost



Cobalt and Nickel free

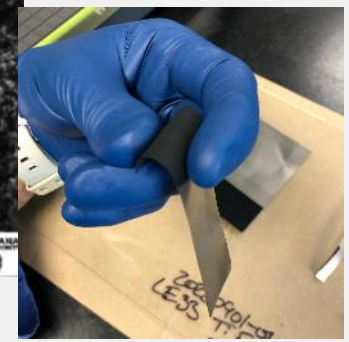
Long life: Demonstrated > 500 cycles 100% DOD @ C/3

CURRENT R&D STATUS AND FUTURE WORK

- We are currently optimizing the stack design, cathode additives, anode additives, and electrolyte dopants
- New cathode binder has increased performance/homogeneity while decreasing cost and eliminating harmful organic solvents
- New electrolyte formulation has shown a significant decrease in zinc shape change in rotating disk electrode testing
- Larger stack designs are being optimized to provide the highest utilization possible at a C/3 rate

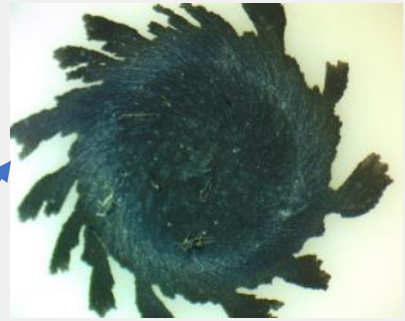
New Aqueous Binder

PVDF / Organic Solvent

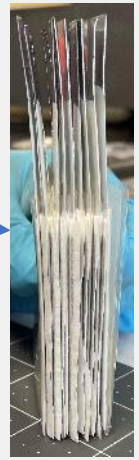


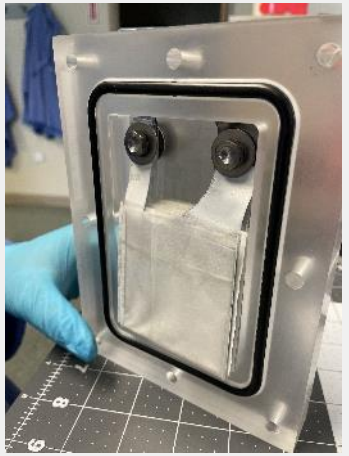
Aqueous Binder Flexibility

Standard Electrolyte



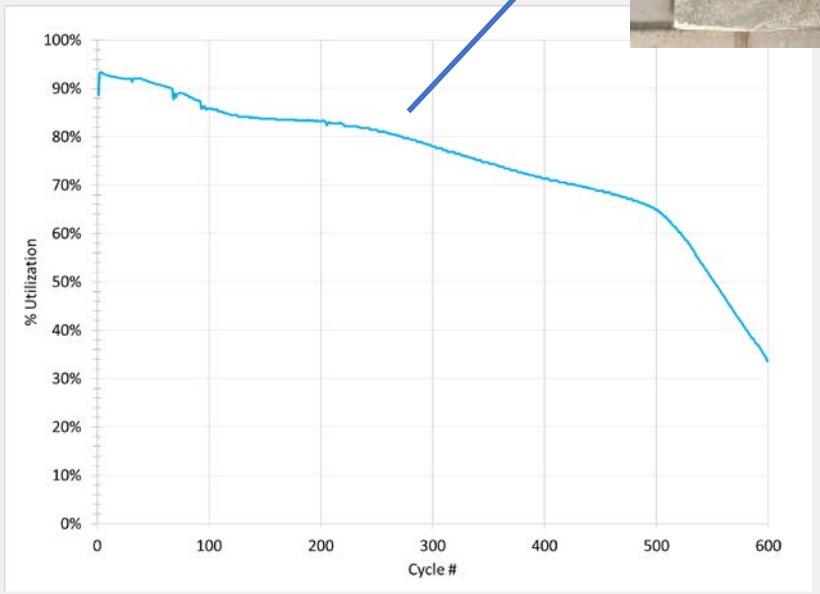
New Electrolyte

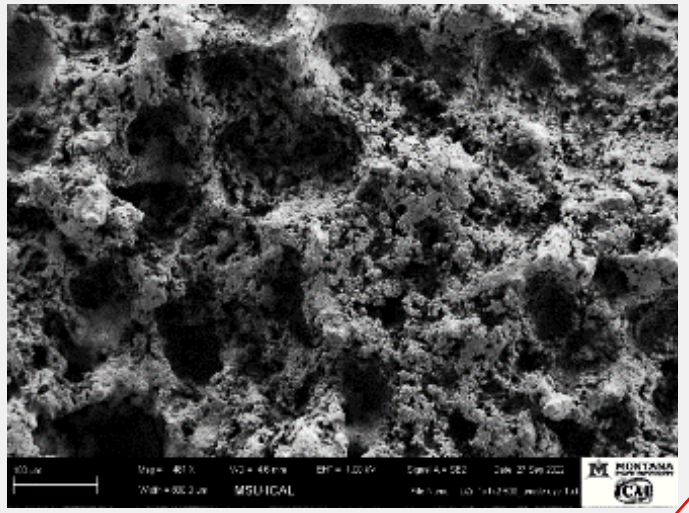


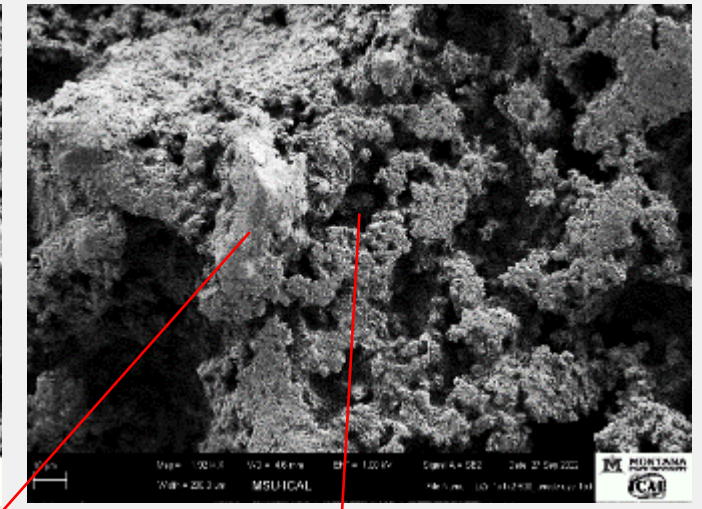


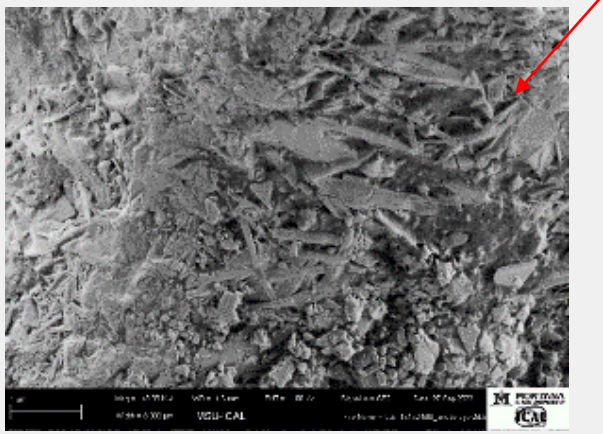
LI-ZN FAILURE MODE

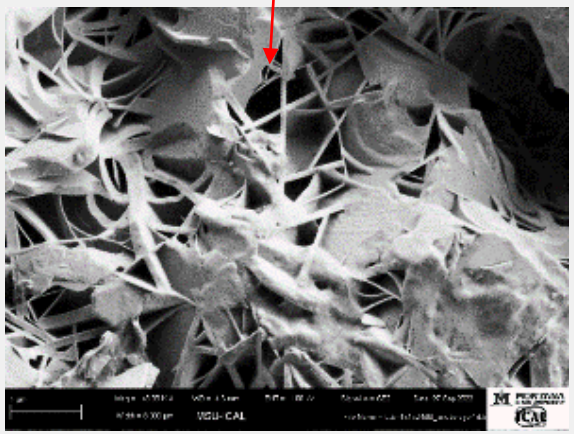
100% DOD C/3 CYCLING









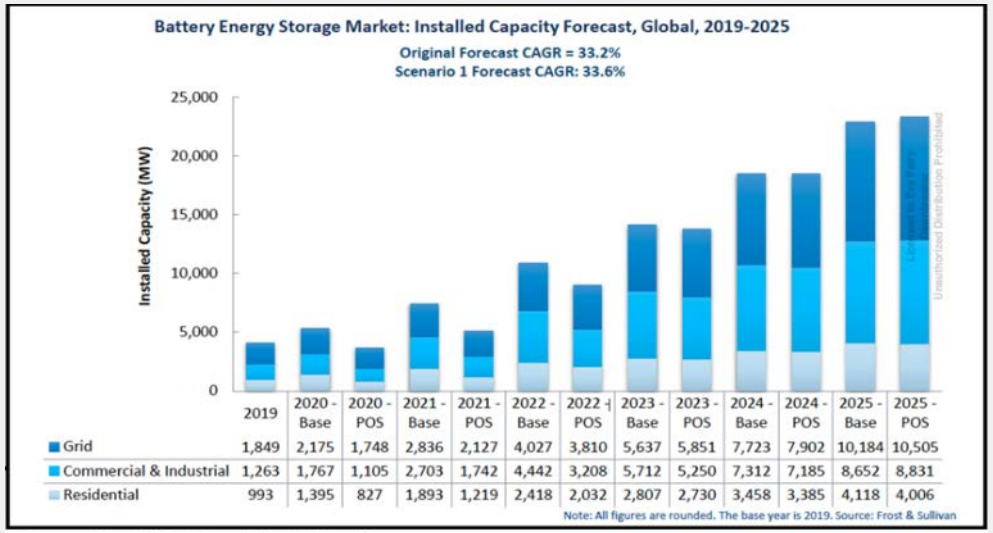


- Nonuniform zinc plating and significant pitting was observed in long running cells.

- Mitigation methods:
  - Additives to anode/electrolyte/separator
  - Modified charging schedules

INITIAL FOCUS MARKET

- After conducting a large number of customer interviews over several months, it was determined that commercial and industrial stationary energy storage would be the best fit for the Li-Zn battery
- It was also determined that the 3 highest pain points were high LCOE, safety concerns, and energy/power density



	2019	2020 - Base	2020 - POS	2021 - Base	2021 - POS	2022 - Base	2022 - POS	2023 - Base	2023 - POS	2024 - Base	2024 - POS	2025 - Base	2025 - POS
Grid	1,849	2,175	1,748	2,836	2,127	4,027	3,810	5,637	5,851	7,723	7,902	10,184	10,505
Commercial & Industrial	1,263	1,767	1,105	2,703	1,742	4,442	3,208	5,712	5,250	7,312	7,185	8,652	8,831
Residential	993	1,395	827	1,893	1,219	2,418	2,032	2,807	2,730	3,458	3,385	4,118	4,006

Note: All figures are rounded. The base year is 2019. Source: Frost & Sullivan

Source: Frost & Sullivan, March 2020[31]

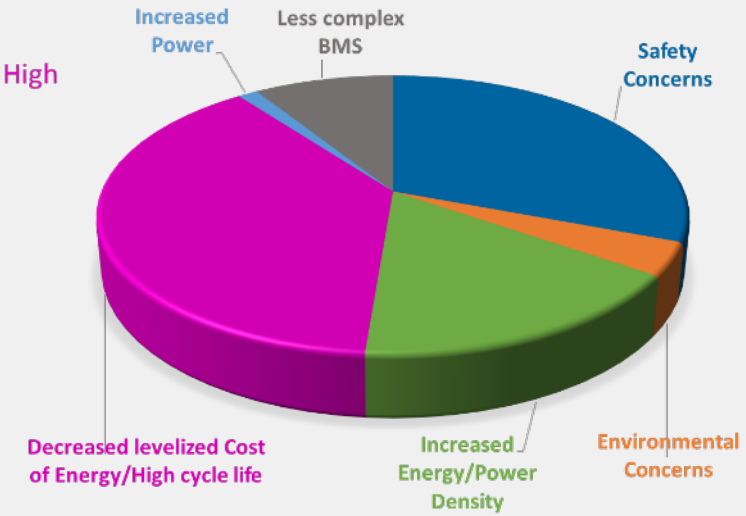
- Estimates have the C&I battery energy storage market growing at a Compound Annual Growth Rate (CAGR) of 33%.
- North America represents the largest portion of the market; however, Cairn ERA predicts Europe and Asia Pacific to outpace the North American market, due to aggressive regulatory incentivization.

What we learned:

Pain Point#1: Decreased levelized Cost of Energy & High cycle life
- Reduction in levelized cost when compared to other technologies
- Need 10-15 year cycle life

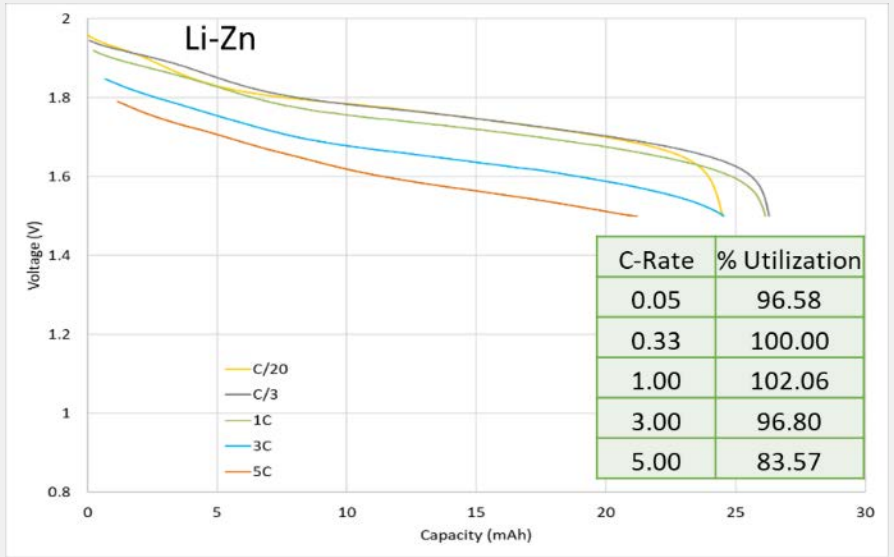
Pain Point #2: Safety Concerns
- New restrictions with Li-ion due to Safety Concerns
- Need to reduce customer anxiety

Pain Point #3: Increased Energy/Power Density
- Smaller footprint needed:
  - New fire codes
  - Space restrictions
  - Reduce floor loadings

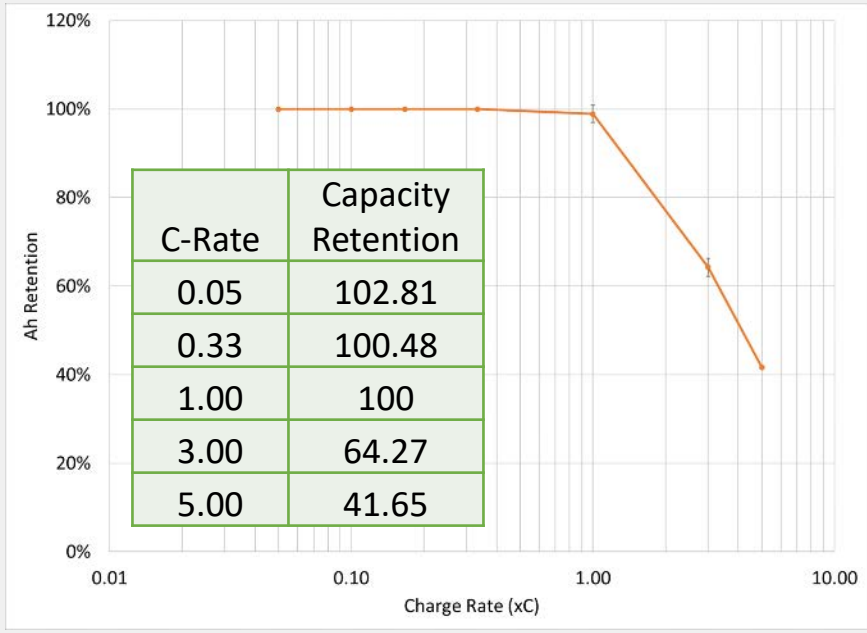


HIGH DISCHARGE RATES AND CHARGE ACCEPTANCE COULD LEAD TO NEW TARGET MARKETS

- The Li-Zn chemistry is mostly being tested at a C/3 rate for stationary energy storage applications; however, the chemistry has performed well at higher C-rates
  - We are also working on integrating new highly conductive materials that will increase utilization at higher C-rates



C-Rate	% Utilization
0.05	96.58
0.33	100.00
1.00	102.06
3.00	96.80
5.00	83.57

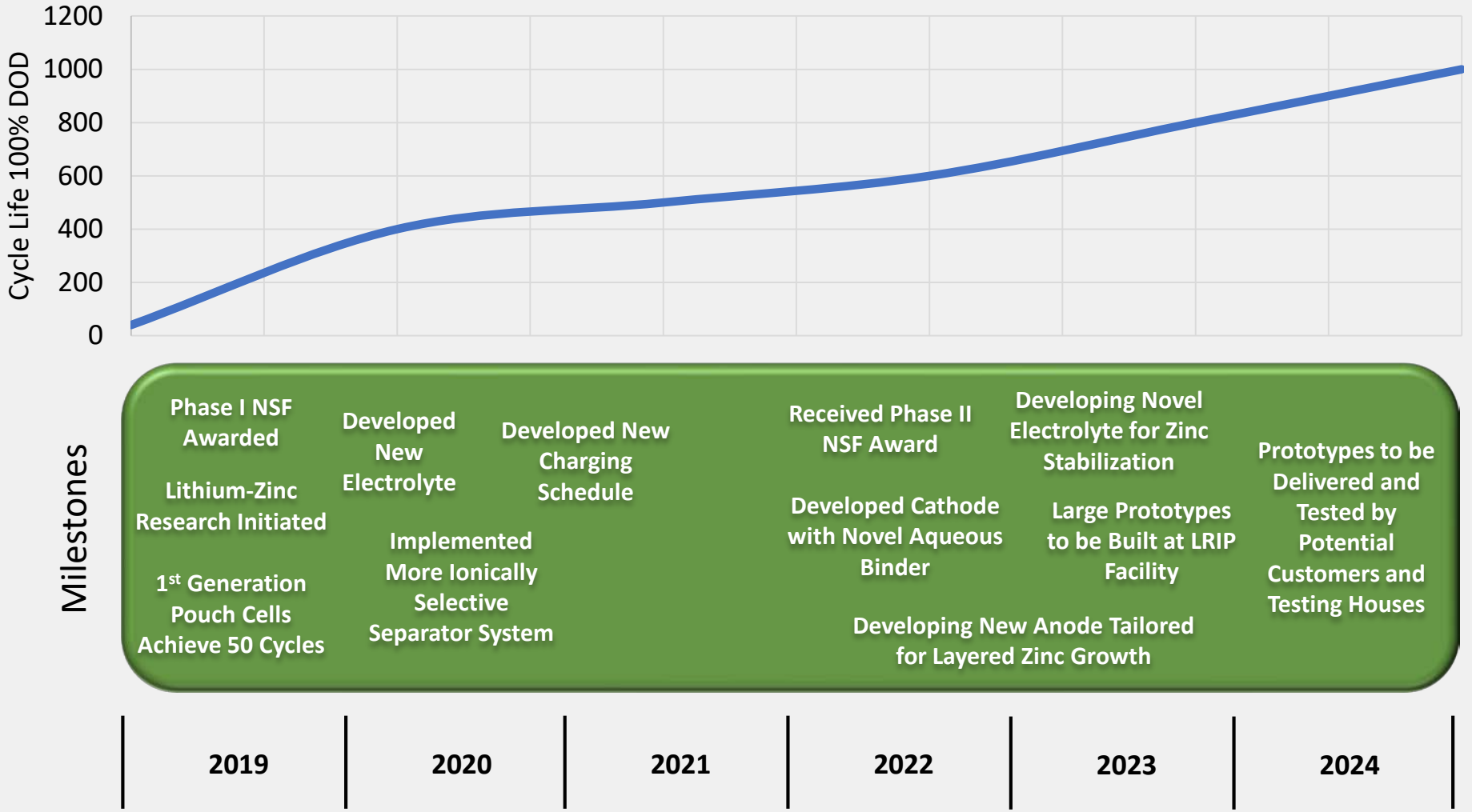


C-Rate	Capacity Retention
0.05	102.81
0.33	100.48
1.00	100
3.00	64.27
5.00	41.65

- The Li-Zn chemistry has also shown the ability to charge quickly and can reach 80% of usable capacity within 37 min
  - Improvements being made for the discharge rate will also impact the charge rate
- These improvements could lead to other potential markets, such as EV charging stations and motive applications

TECHNOLOGY ROADMAP

OVERVIEW



THANK YOU

Contact

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