



# 650 Wh/kg, 1400 Wh/L Rechargeable Batteries for New Era of Electrified Mobility

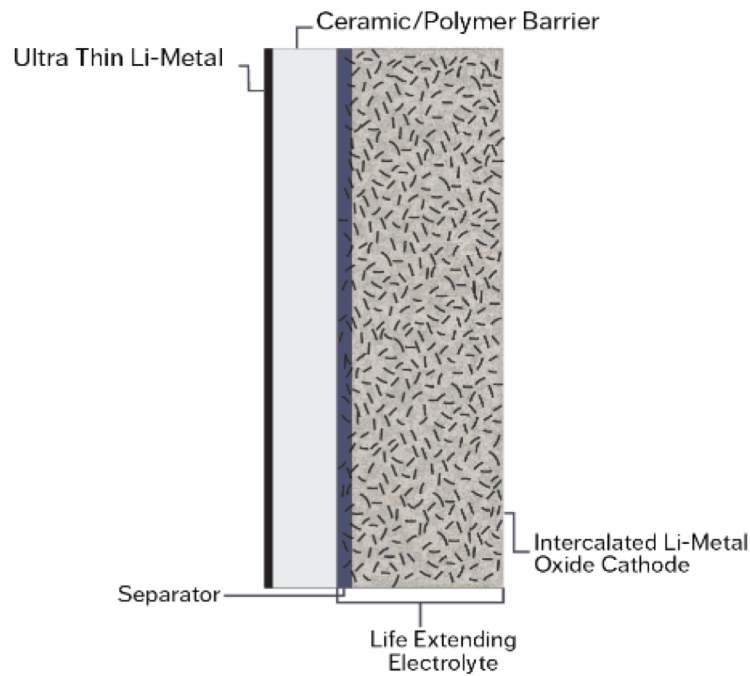
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Our **mission** is to enable and enhance freedom on land, sea, and air.

# Licerion<sup>®</sup> Topics

- Sion Power's New Licerion Technology Provides a Solution Beyond Conventional Li-Ion
  - Key elements of Licerion technology
  - Road map to ultra high energy
- Sion Power/BASF Development of Licerion Batteries for Diverse Applications
  - Current state of Energy Density
  - Cycle Life
  - Rate Capability
  - Thermal Stability
  - Low Temperature Performance
- Licerion Cells Availability

# Key Elements of Licerion<sup>®</sup> Technology



- Physical Protection of Lithium Metal Anode with Thin, Chemically Stable and Ionically Conductive Ceramic/Polymer Barriers
- Spectra of Chemical Protections
  - Electrolyte additives forming protective film on the anode to extend cycle life
  - Stabilized electrodes enhancing cycle life and increasing energy
- Cell Designs Which Maximize Energy and Control Lithium Morphology During Extended Cycling
- 50% Reduction in Liquid Electrolyte Volume Versus Conventional Li-Ion Technology

## Strategic Advancement

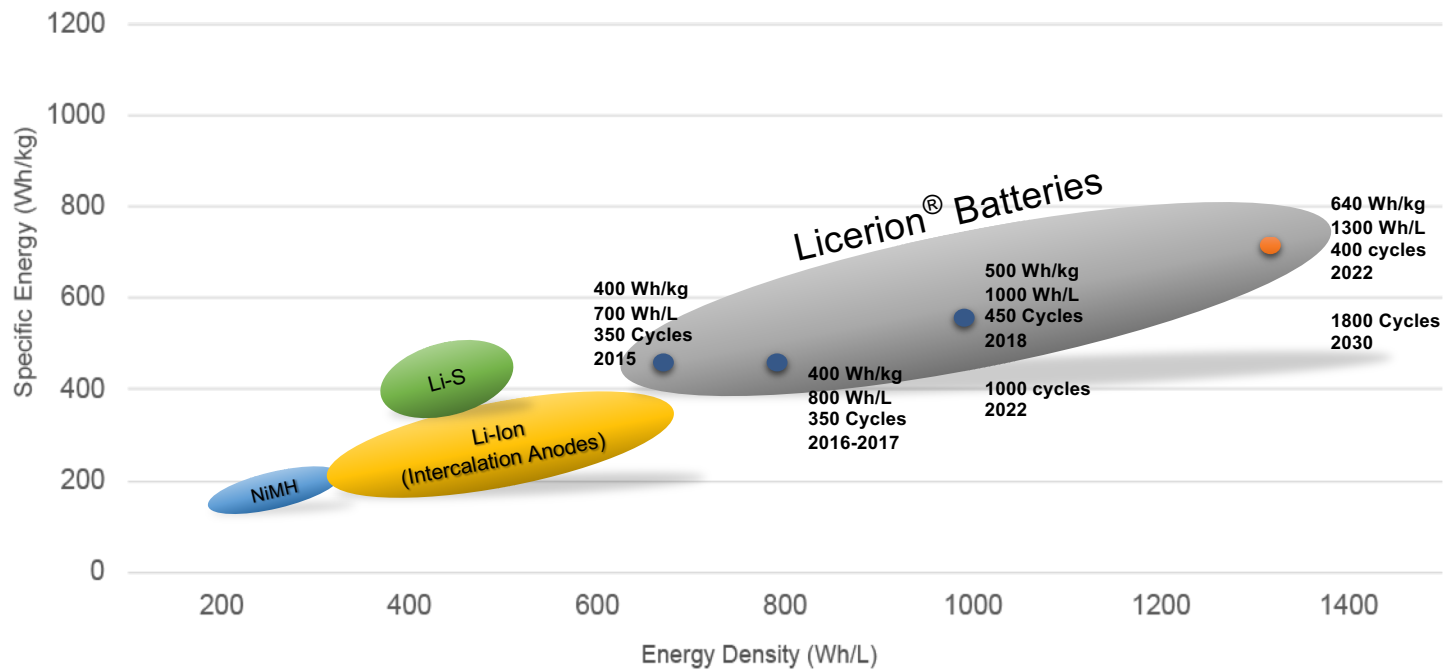
In 2015 Sion Power Made a Strategic Decision to Transition from Lithium-Sulfur to Lithium-Metal Oxide Rechargeable Battery Technology.



## Extending Licerion<sup>®</sup> Technology to Intercalation Cathodes

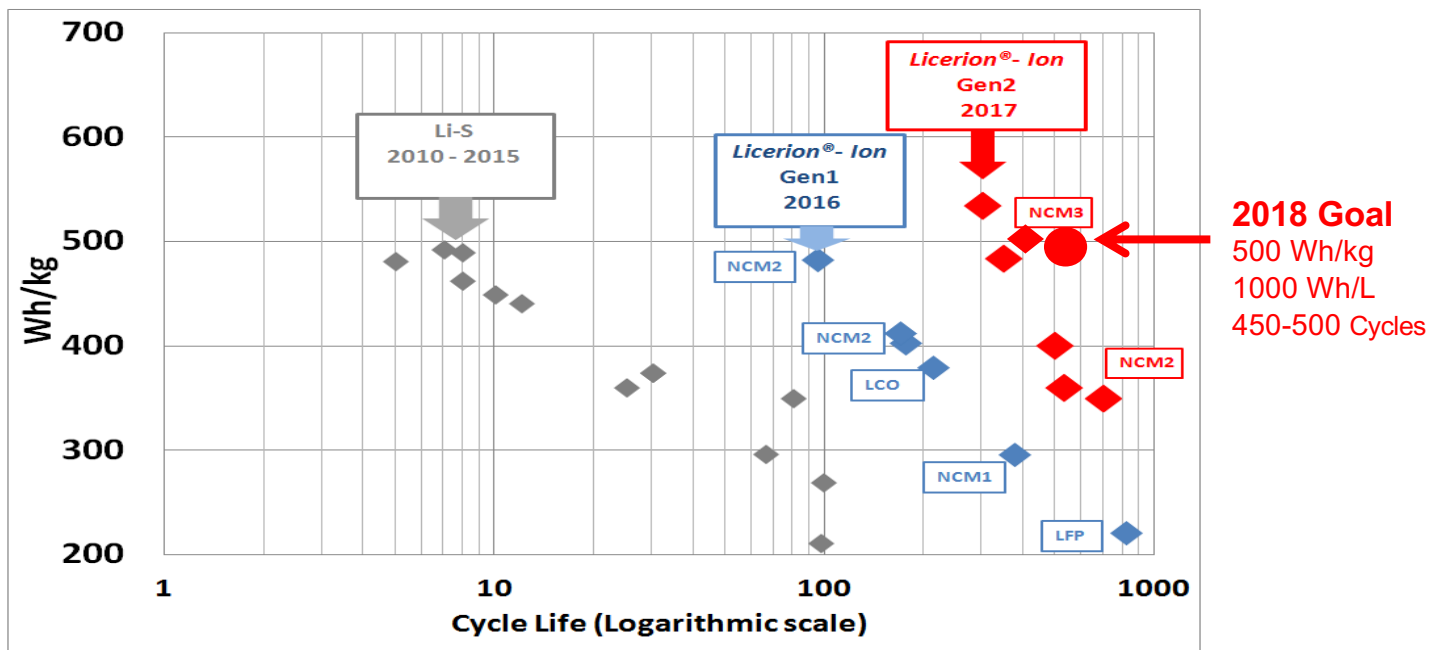
- Intercalation Li-Metal Oxide Cathodes are Well Developed by Li-Ion Battery Industry and Have Reached Technological Maturity.
- High Quality Intercalation Cathodes are Available from Variety of Sources including BASF Partners.
- Licerion-Ion Battery Production is Compatible with Existing Li-ion Manufacturing Processes.

# Roadmap to Ultra High Energy Density



Intercalation cathodes coupled with Licerion protected Li offer higher energy density compared with other systems.

# Licerion<sup>®</sup>-Ion Progressing Rapidly



Protected lithium anode, electrolyte system and Ni-rich NCM cathode enable rapid progress in energy densities and cycle life.

# What Cycle Life is Good Enough?



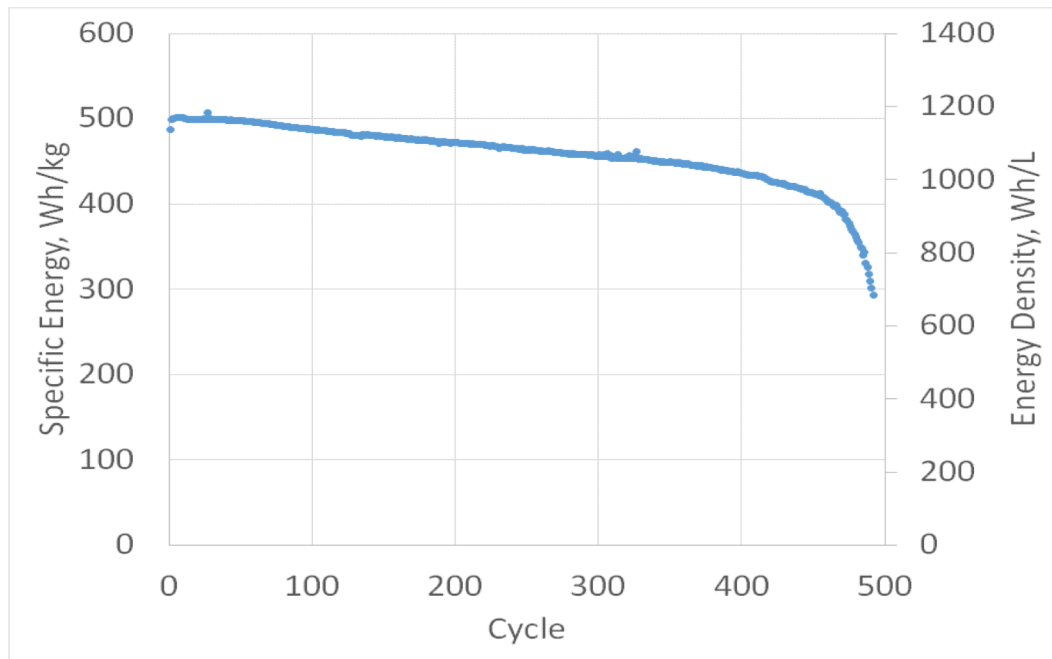
Car Life Expectancy = Driving Range x Cycle Life

A diagram showing the calculation of car life expectancy. Three gray arrows point downwards from the terms in the equation above. The first arrow points to "200, 000 miles", the second to "400 miles", and the third to "500 Cycles".

$$200,000 \text{ miles} = 400 \text{ miles} \times 500 \text{ Cycles}$$



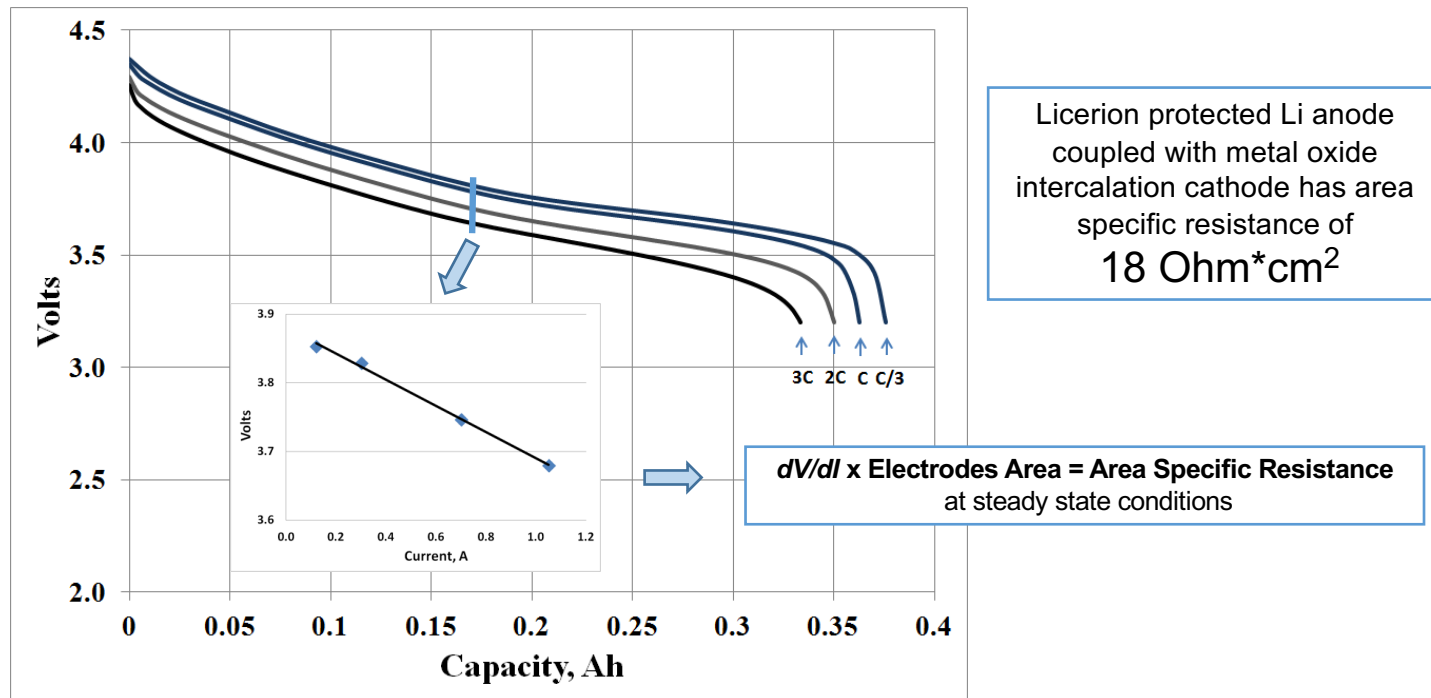
# Licerion<sup>®</sup> Achieves 2018 Goal: 1000 Wh/L, 500 Wh/kg, > 450 Cycles



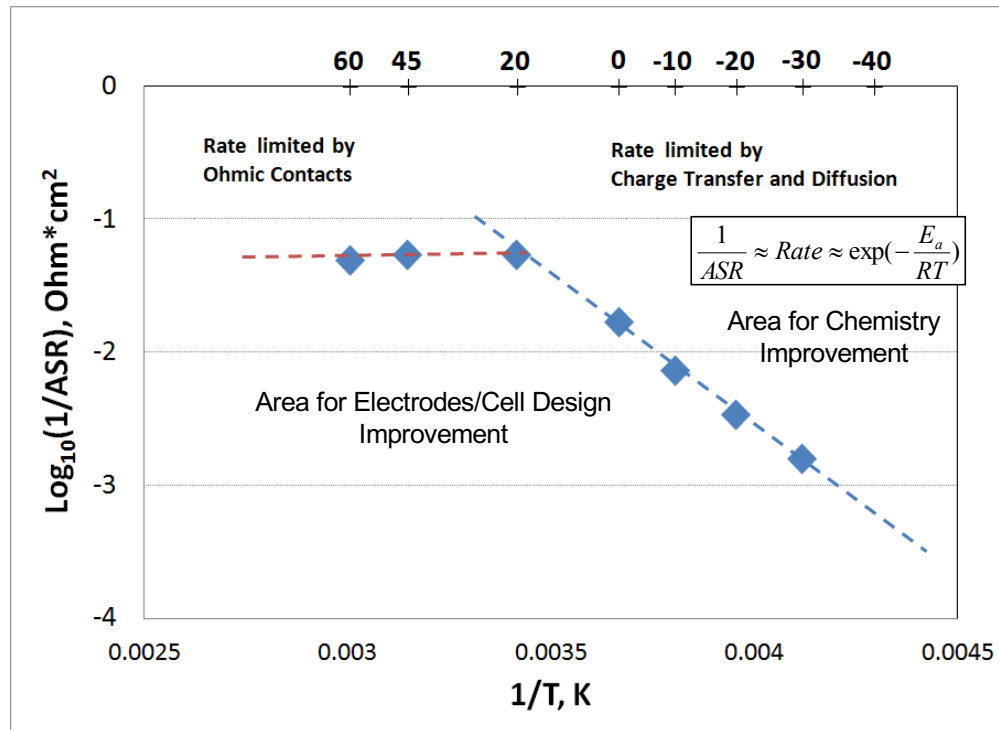
Specific energy and energy density projected to 10 cm x 10 cm x 1 cm cell design using same active materials balance as 0.4 Ah cells and accounting for weight and volume of all large cell components.

- 2018  
Licerion exceeded 500 Wh/kg, 1000 Wh/L, and >450 cycles in 0.4 Ah development cells. Projected specific energy and energy density were confirmed in the actual large cells.
- 2019  
Scale-up and commercialize in large cell format
  - 26 Ah cell
  - 10 cm x 10 cm x 1 cm

# Licerion<sup>®</sup> Li Anode Protection Leads to Low Cell Electrical Resistance



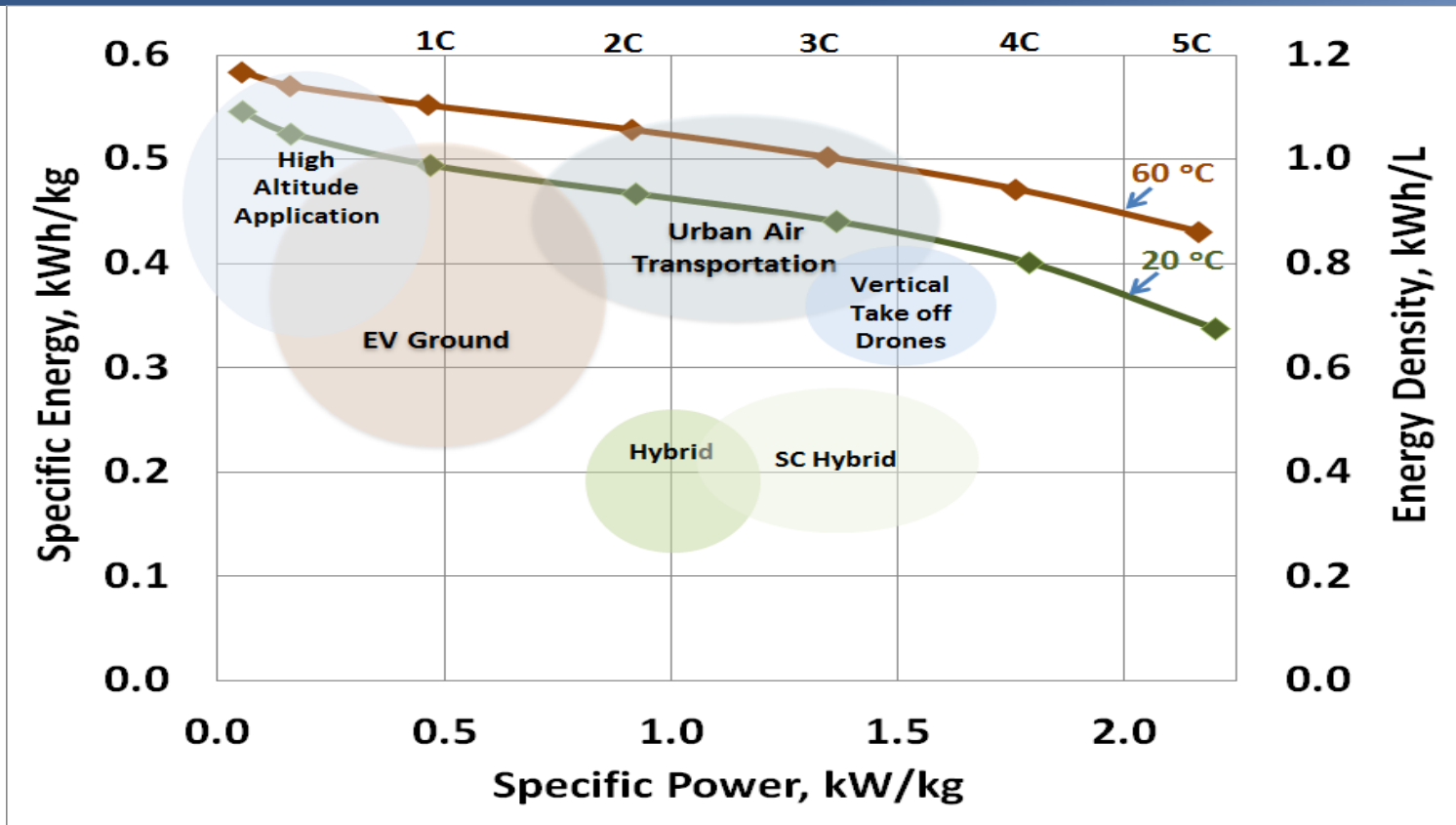
# Strategy to Improve Rate Capability



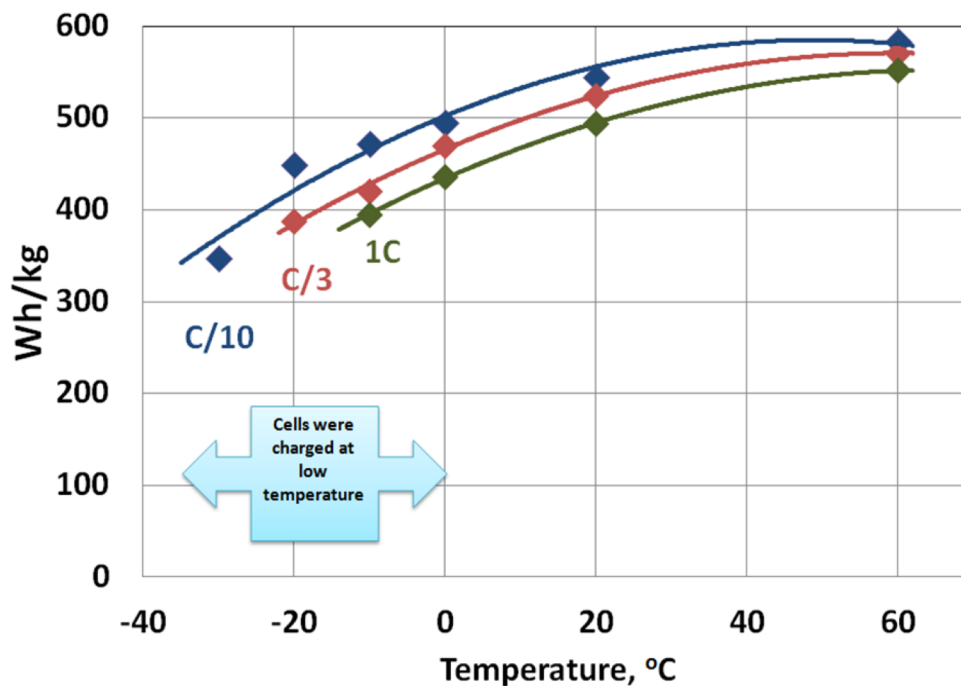
Arrhenius plot of ASR as a function of temperature

Area Specific Resistance (ASR) – Temperature Dependence Gives Insight into What Controls Cell Rate Capability at Low and Elevated Temperatures

# High Combination of Power and Energy



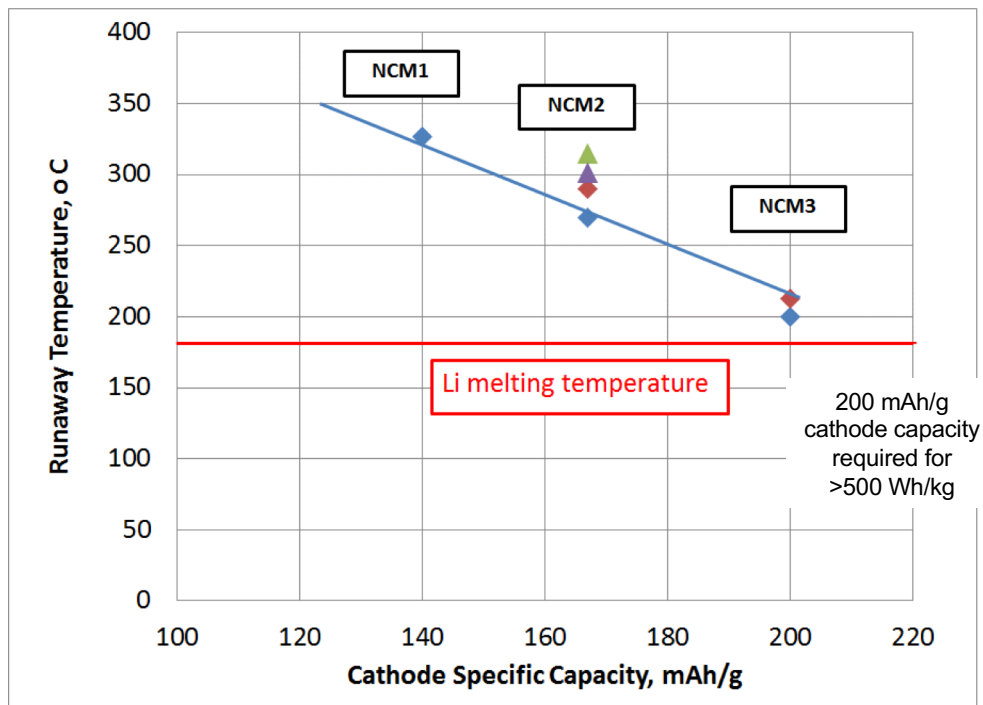
# High Specific Energy Over a Wide Temperature Range



- Licerion<sup>®</sup> Cells Provide Good Power and Energy Over Wide Range of Rates
- Higher temperatures yield higher specific energy

Specific Energy Delivered at Various Temperatures and Discharge Rates

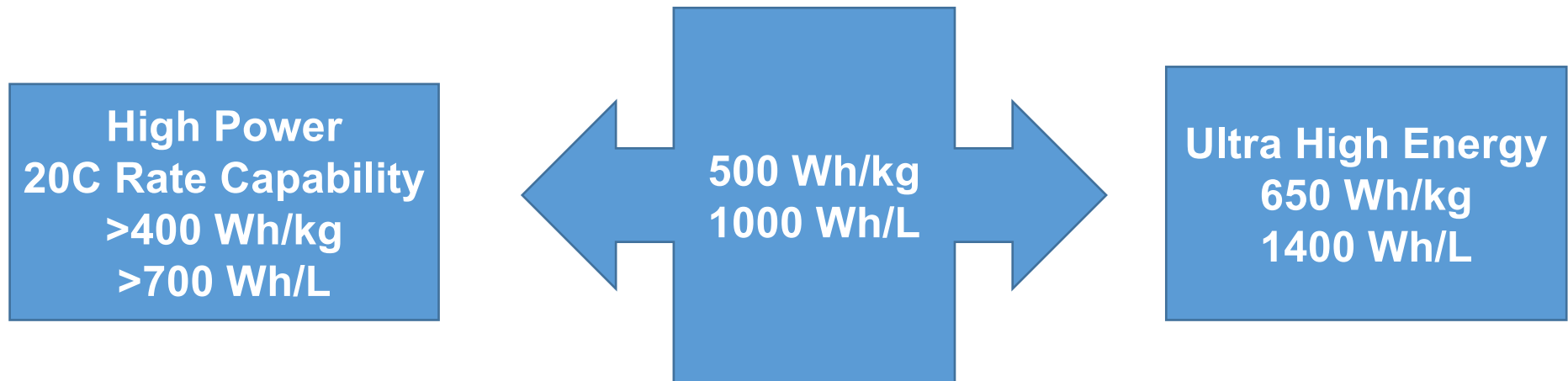
# Stability of Licerion<sup>®</sup> Technology in Abuse Testing



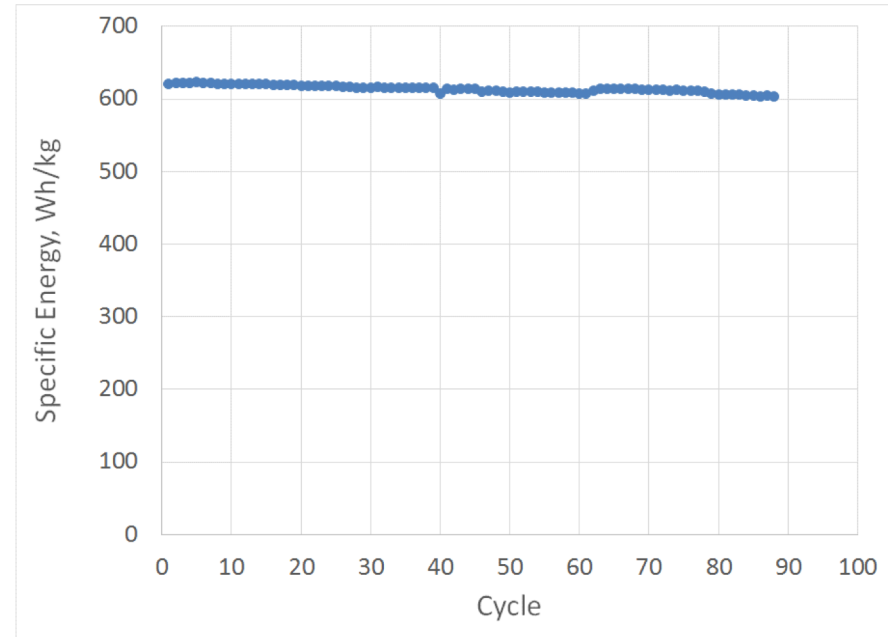
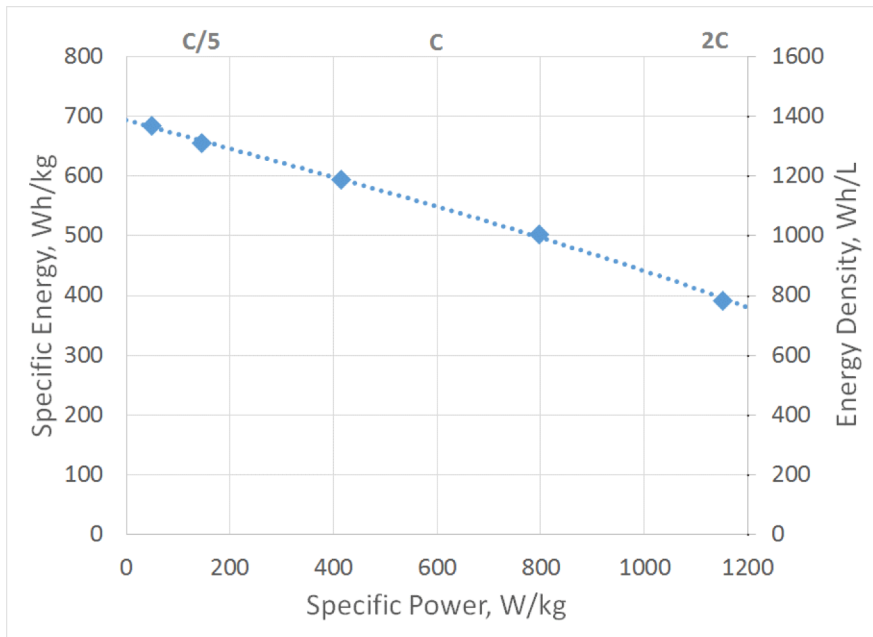
Thermal Stability of 6 Ah Licerion Cells

- Thermal Stability is Determined by the Choice of Cathode Material (not Anode)
- Licerion<sup>®</sup> Cell is Thermally Stable Until Above 200°C
  - Verified Licerion 1 and 2
- 6 Ah Licerion 1 Passed the Following Abuse Tests:
  - External Short, 100% SOC
  - Over-charge
  - Over-discharge
- Planned:
  - Nail Penetration
  - 3<sup>rd</sup> Party Validation
  - 10 and 20 Ah Cell
  - UN certification

# Licerion<sup>®</sup> Technology Variations



# Ultra High Energy Licerion<sup>®</sup> Cells

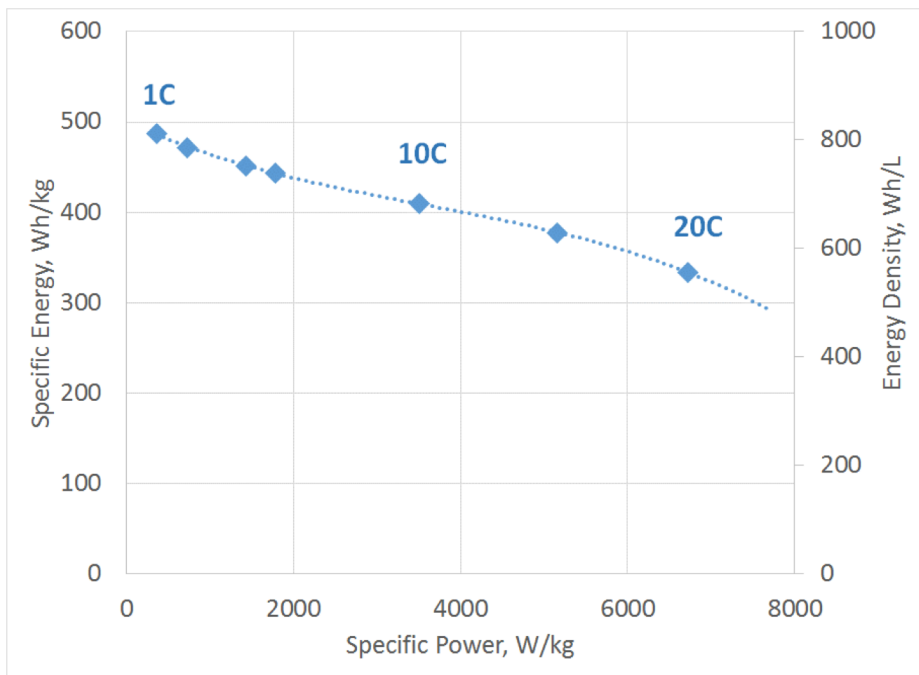


Note: test in process, early results

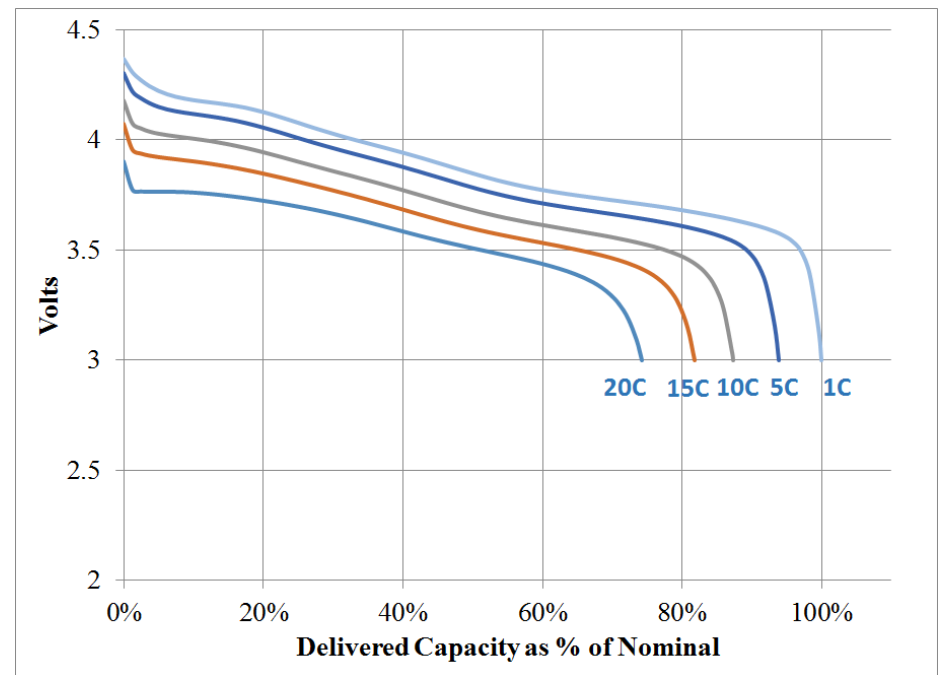
Energy up to 700 Wh/kg and 1400 Wh/L



# High Power Licerion<sup>®</sup> Cells

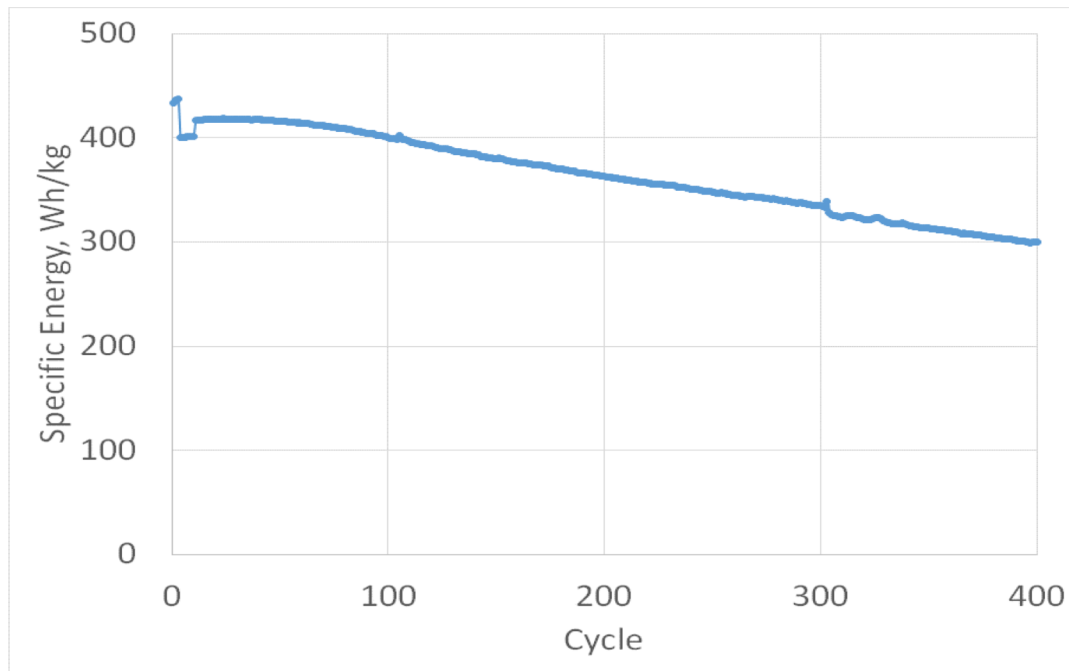


Energy Over 70% at 20C Discharge Rate



Capacity Over 75% at 20C Discharge Rate

# High Power Licerion<sup>®</sup> Cells



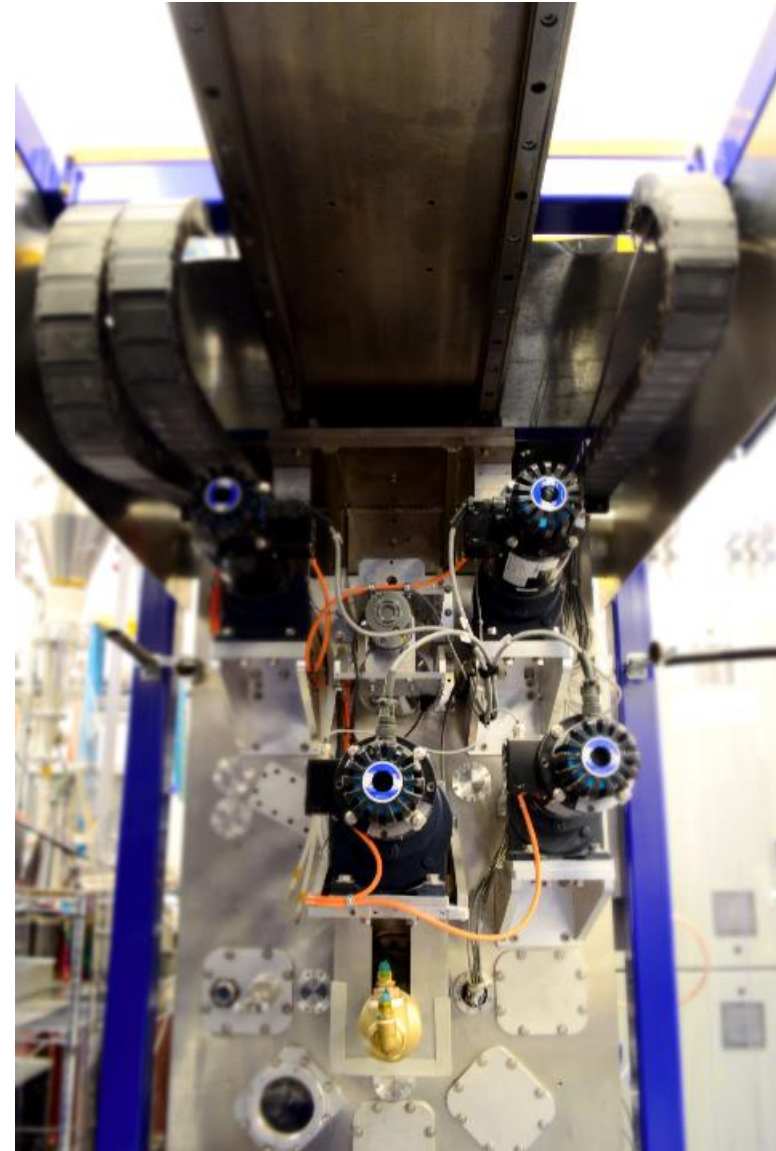
Energy Over 400 Wh/kg  
and 700 Wh/L

Discharge Rates up to 4 -10C

Charge Rates up to 1C

# Summary

- **Licerion**<sup>®</sup> Technology Offers Extended Driving and Flying Ranges for Diverse Electrified Mobility Applications through the application of Advanced Metallic Lithium Protection Systems
- Specific Energy, Energy Density and Cycle Life Have Reached 500 Wh/kg and 1000 Wh/L and Over 450 Cycles
- High Energy Licerion Cells Offer up to 700 Wh/kg and 1400 Wh/L
- High Power Licerion Cells Offer Rate Capability up to 20C and Specific Power up to 8 KW/kg at Continuous Discharge
- Sion Power is Developing Partnerships for Commercialization and Volume Manufacturing to Supplement in-house Production Capacities for a Variety of Markets





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