# Liquefied Gas Electrolytes
## for Next-Generation Lithium Batteries

**Charlie Krause**, Ph.D. | fckrause@south8technologies.com
Senior Battery Scientist | **South 8 Technologies, Inc.**

40th Annual Space Power Workshop | Redondo Beach, CA
27th April 2023

# Advancing a Clean Energy Future

SOUTH 8 TECHNOLOGIES

**Founded in 2016 | San Diego, CA**

Spin out from UC San Diego where the Liquefied Gas Electrolyte (*LiGas*) chemistry was first developed

## Team

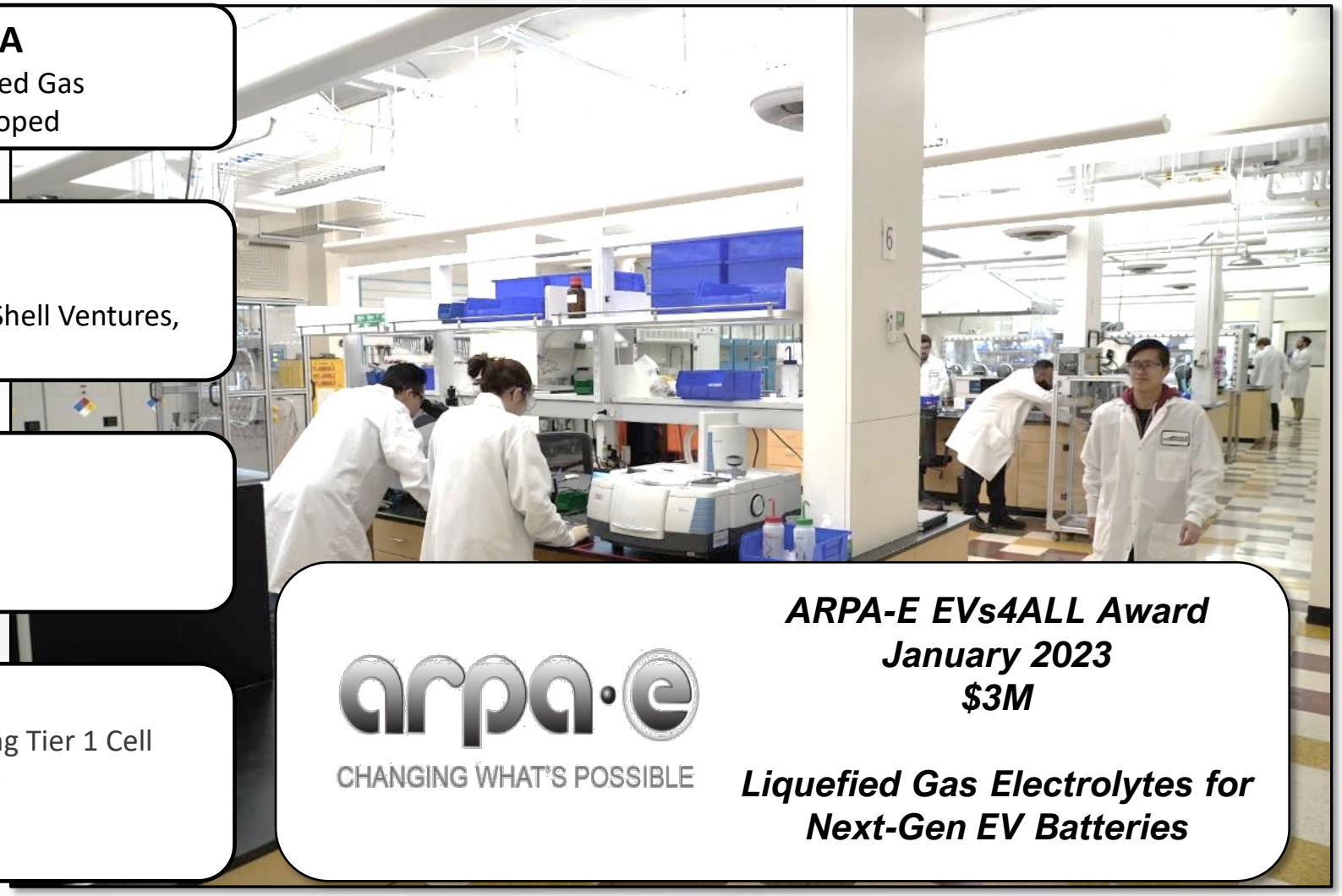
- 24 Full-Time Employees
- Prominent Series-A Investors Including LG Ventures, Shell Ventures, Anzu Partners, Foothill Ventures, Taiyo Nippon Sanso

## IP Portfolio

- 7 Separate Patent Families Issued in U.S.
- Several International Patents Issued
- Continual IP Generation

## Traction

- Technology Validated by 3rd Party Validated by Leading Tier 1 Cell and Automotive Manufacturers and Dept. of Defense
- Several Purchase Orders Across Industry Segments
- Ongoing Joint Development Projects



arpa·e
CHANGING WHAT'S POSSIBLE

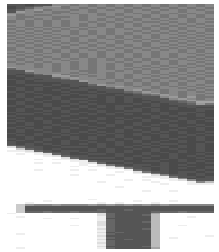
***ARPA-E EVs4ALL Award***
***January 2023***
***$3M***

***Liquefied Gas Electrolytes for Next-Gen EV Batteries***

# LiGas Electrolytes for Any Cell

SOUTH 8 TECHNOLOGIES

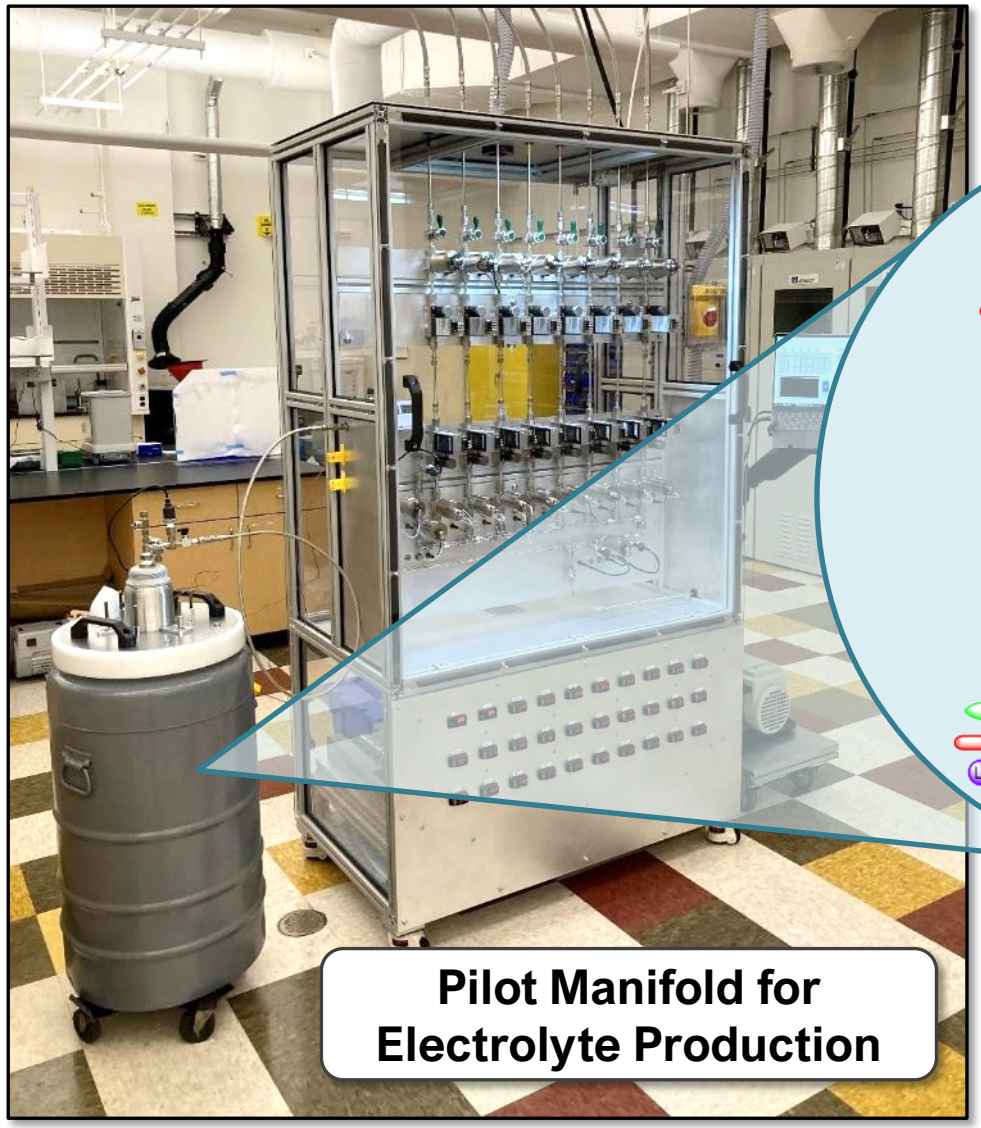
**South 8 is focused on electrolyte development and electrolyte filling**
**Maintaining compatibility with all Li-ion jelly rolls**

| Materials Supplier | Dry-Cell Manufacturing | Cell Production | Product Integrator |
|---|---|---|---|
| BASF We create chemistry | LG Energy Solution | SOUTH 8 TECHNOLOGIES *Electrolyte Fill* | TESLA |
| TODA AMERICA | EnerSys |  | HYUNDAI |
| TAIYO NIPPON SANSO | Panasonic | *Manufacturing Partners* | BOEING |
|  | SAMSUNG | | Mercedes-Benz |
| CELGARD | SAFT, SONY, BYD | | Ford, CAT, BYD |

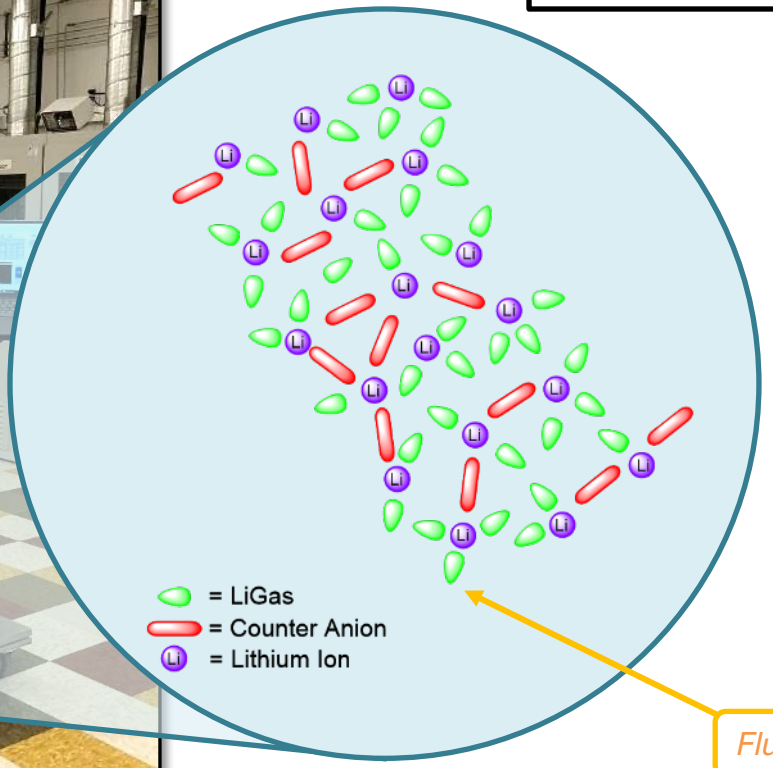
*South 8 Technologies, Inc. maintains non-publicly-disclosed partnerships. Companies listed herein are examples not intended to declare or imply any relationship with South 8 Technologies, Inc.*

# Liquefied Gas Solvent Electrolytes

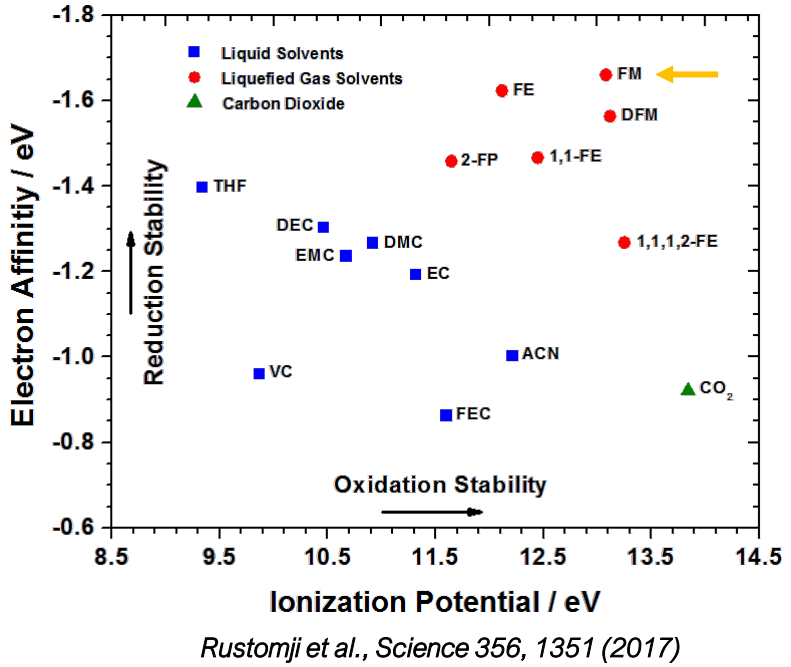
SOUTH 8 TECHNOLOGIES



Pilot Manifold for Electrolyte Production




**Calculated via DFT at B3LYP/6-31+g(d,p) level of theory.**




*Rustomji et al., Science 356, 1351 (2017)*

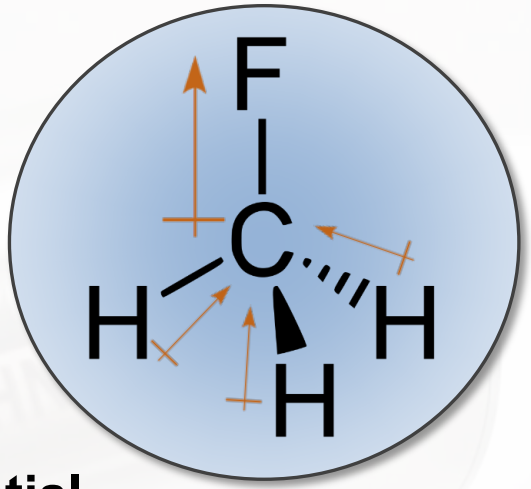
*Fluoromethane: the only publicly disclosed LiGas component*

- ***Liquefied gas blends form electrolyte solutions analogous to traditional formulations***
- ***Excellent electrochemical stability windows predicted***

# LiGas: Desirable Properties

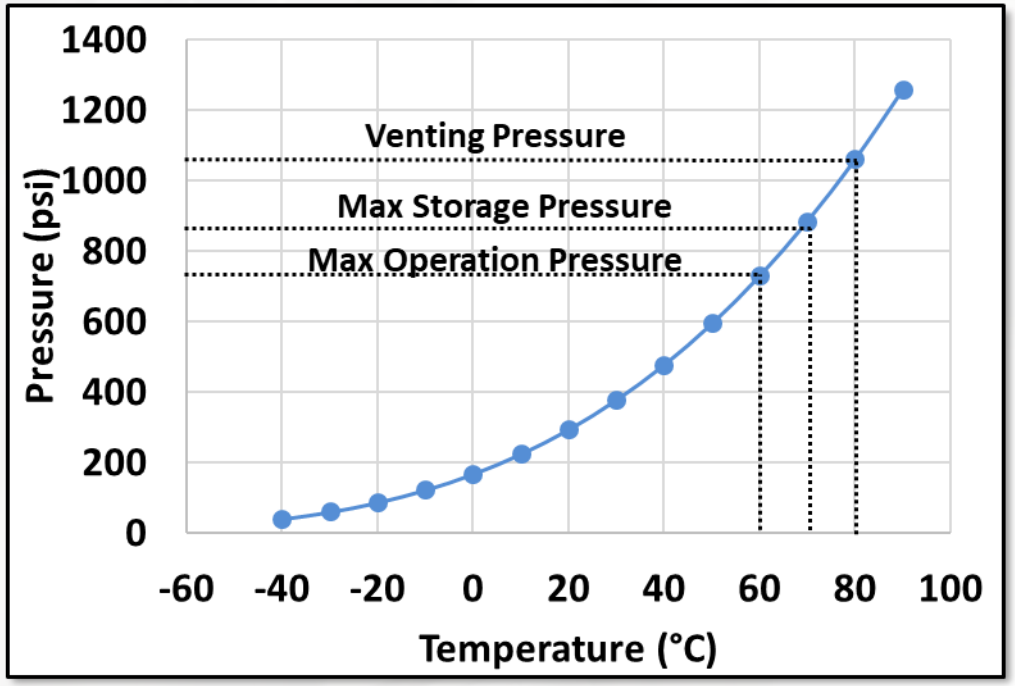
SOUTH 8 TECHNOLOGIES

**Fluoromethane is used in combination with other proprietary gaseous solvents to create high performance *LiGas* electrolytes**




- Cost-Effective
- Low Viscosity
- Low Melting Points
- Non-Toxic, Non-Corrosive
- Non-Ozone-Depleting
- Low Global Warming Potential
- Excellent Electrochemical Stability
- Commercially Available in High Purity
- Compatible With All Common Battery Materials

**Typical Vapor Pressure Curve for *LiGas* Cell**




**Always working towards lower vapor pressure electrolytes**

# Implementing LiGas: Cylindrical Packaging

SOUTH 8 TECHNOLOGIES

**Pre-A Cells: Higher TRL Sample Cells**

- Standard form-factor
- Low impedance: high power capable
- Laser welded for hermetic sealing
- High temperature capable
- Easier manufacturing

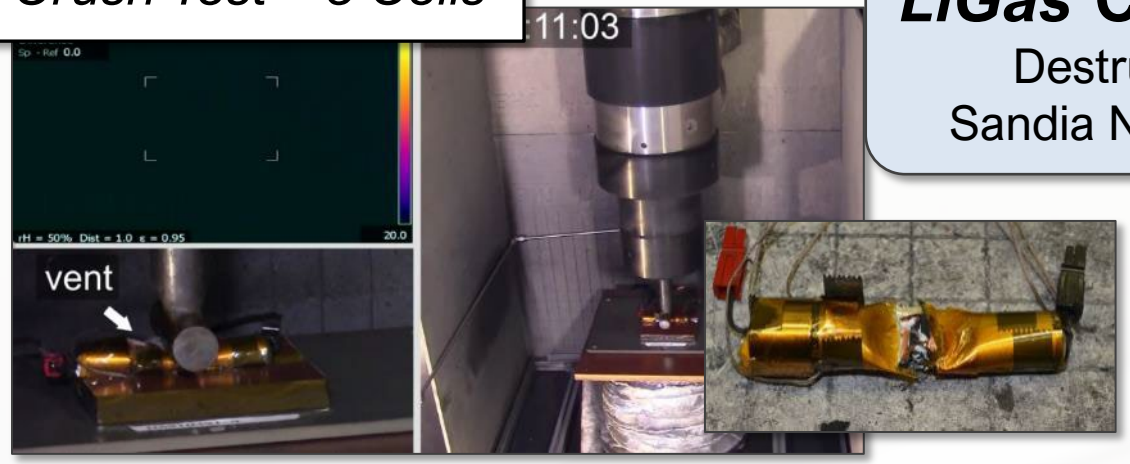

**Prototype Cells: Chemistry Demonstration**

- Non-standard cap form-factor
- High impedance positive pin
- Electrolyte leakage at high temperature
- Difficult manufacturing
- ➢ ***Supplier COTS cans can handle LiGas pressure***

# LiGas Advantages: Safety

SOUTH 8 TECHNOLOGIES

*Crush Test – 3 Cells*

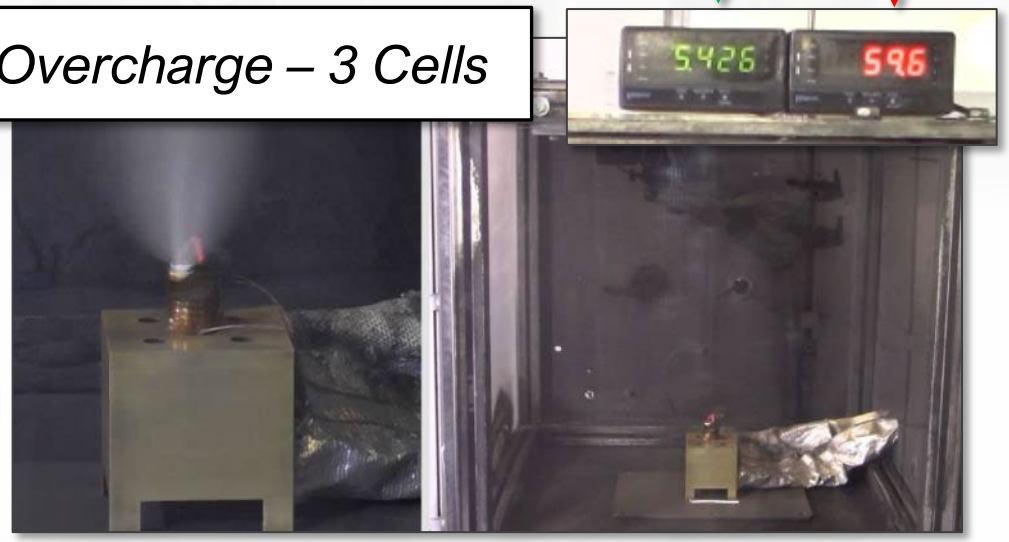



**_LiGas_ Cells Fail Safely**
Destructive testing at
Sandia National Laboratory

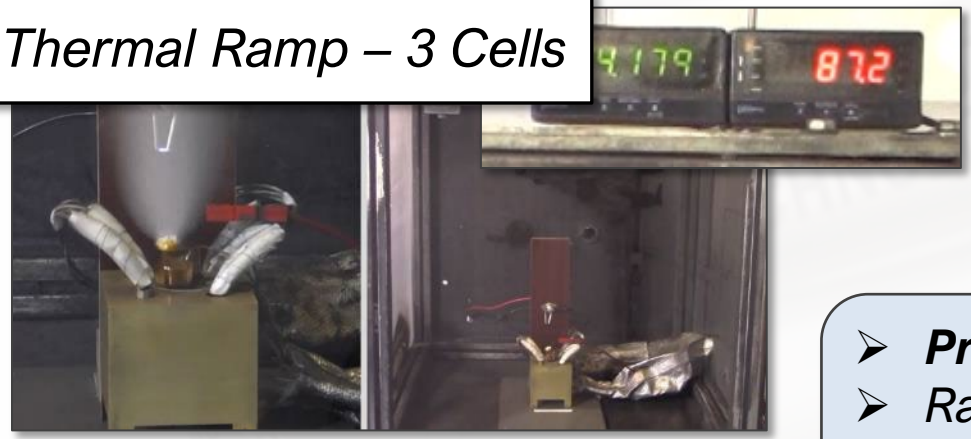
**2 Ah Graphite-NMC622**
**18650 Cells**

**Voltage** **Temperature**

*Overcharge – 3 Cells*



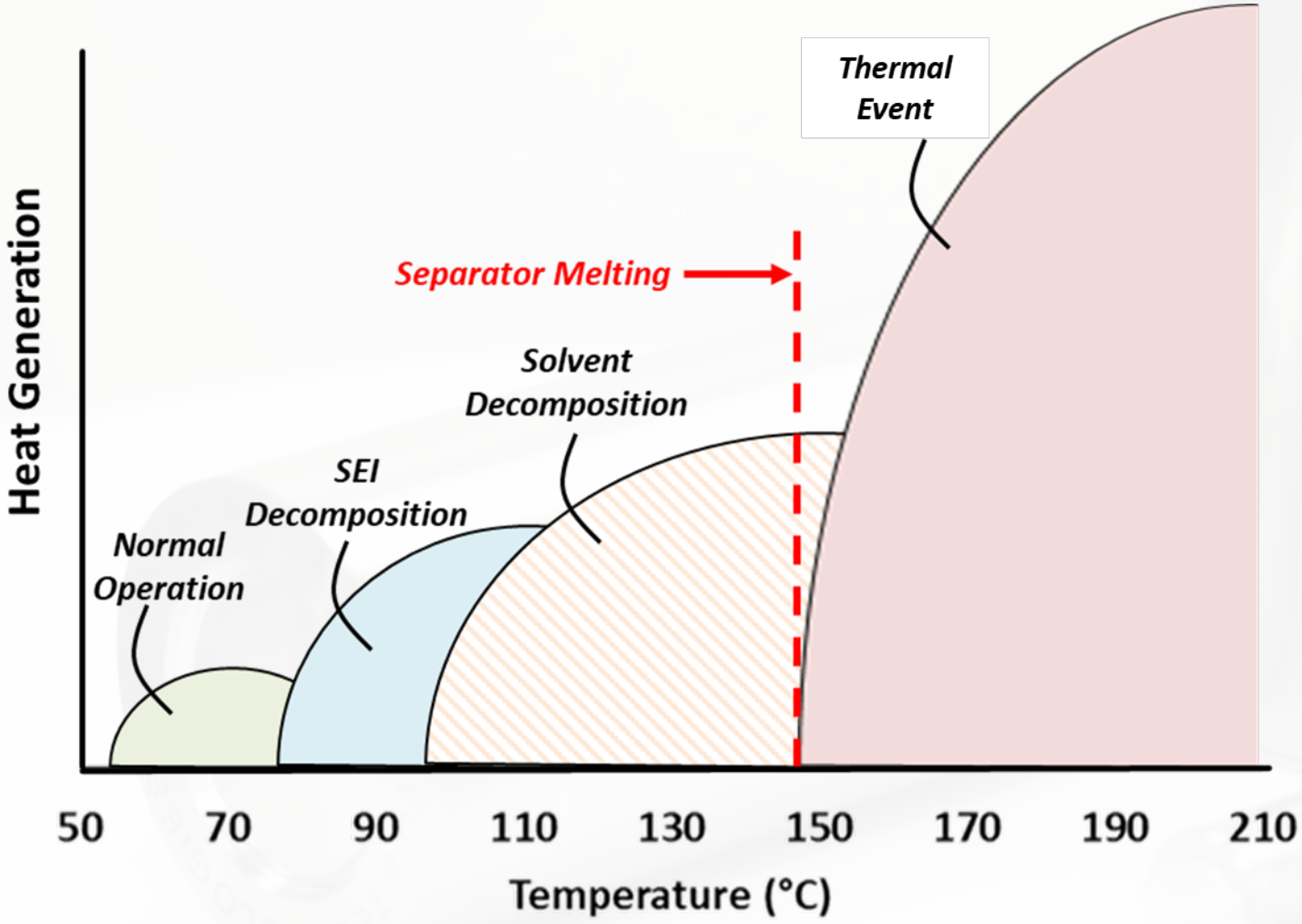

*Thermal Ramp – 3 Cells*



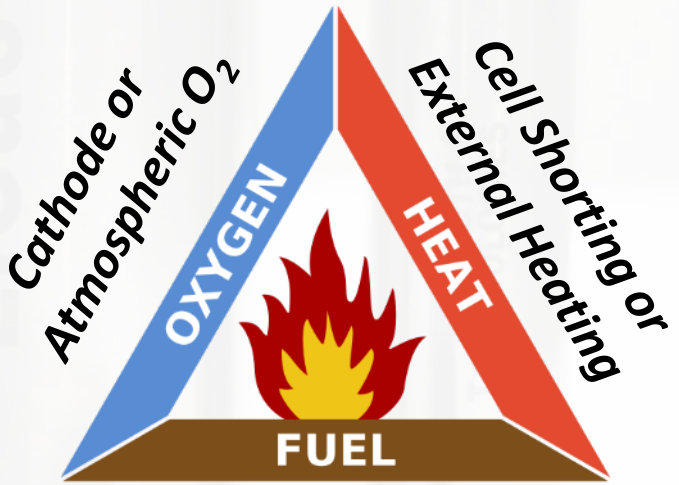

- ***Pressure can be a safety advantage***
- *Rapid venting of LiGas solvents and evaporative cooling of the cell*
- *Vented LiGas appears sparingly or non-flammable: spark igniters in vent path had no effect*

# Venting Electrolyte Reduces Fuel

SOUTH 8 TECHNOLOGIES




***As soon as the can is breached, liquefied gasses immediately vaporize and vacate the cell***



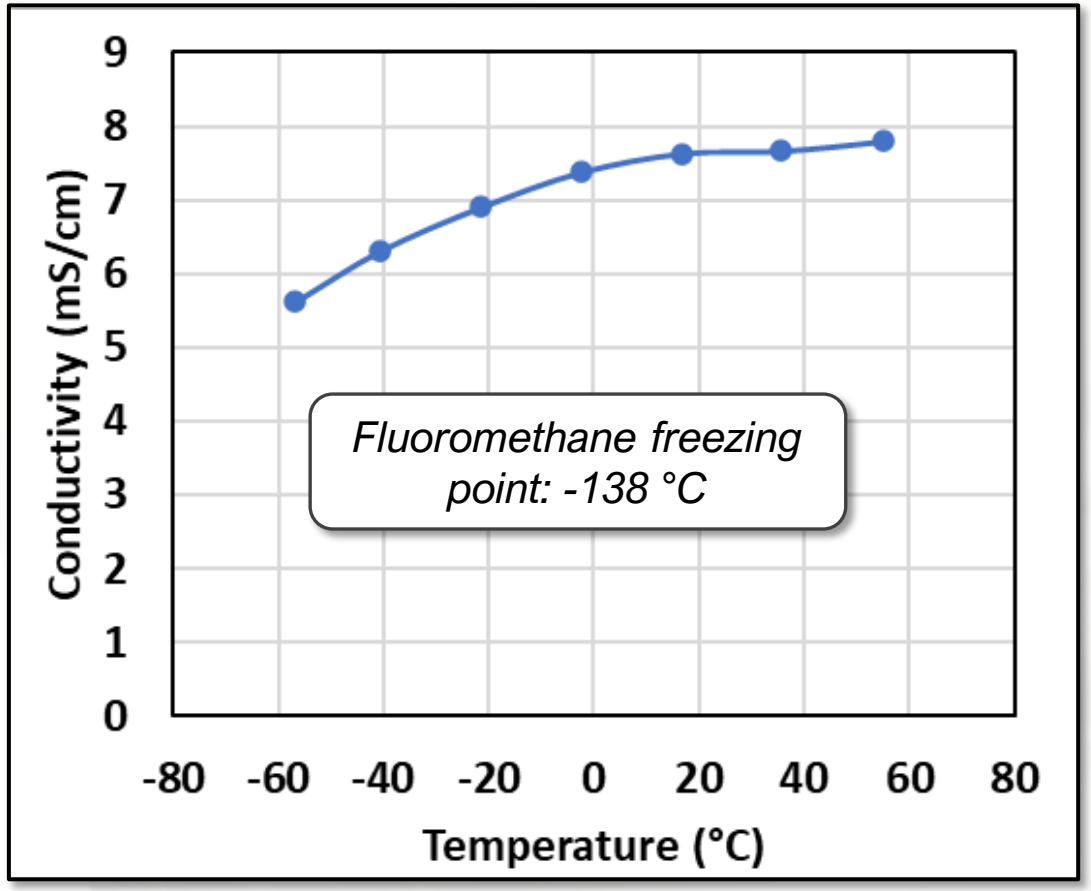

***Graphite***

***~~Electrolyte~~***

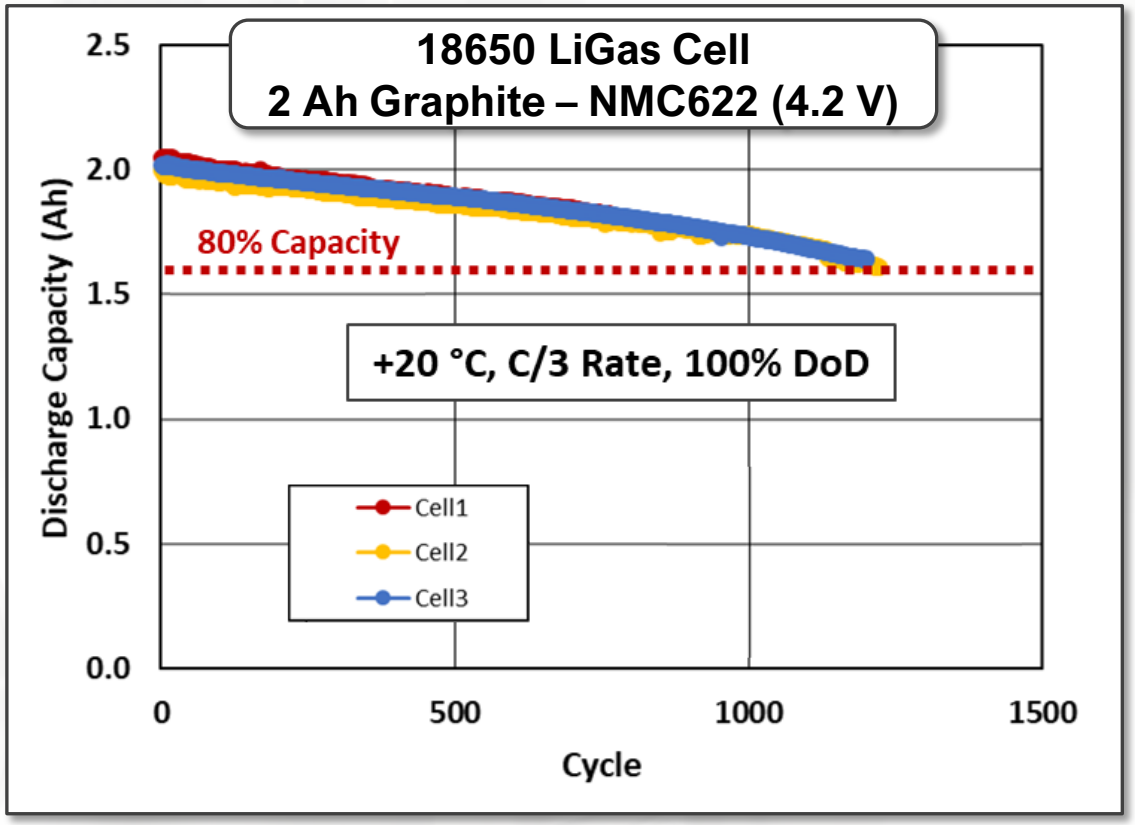
**Less Fuel = Safer Cell**

# LiGas Electrolytes: Fully Functional

SOUTH 8 TECHNOLOGIES



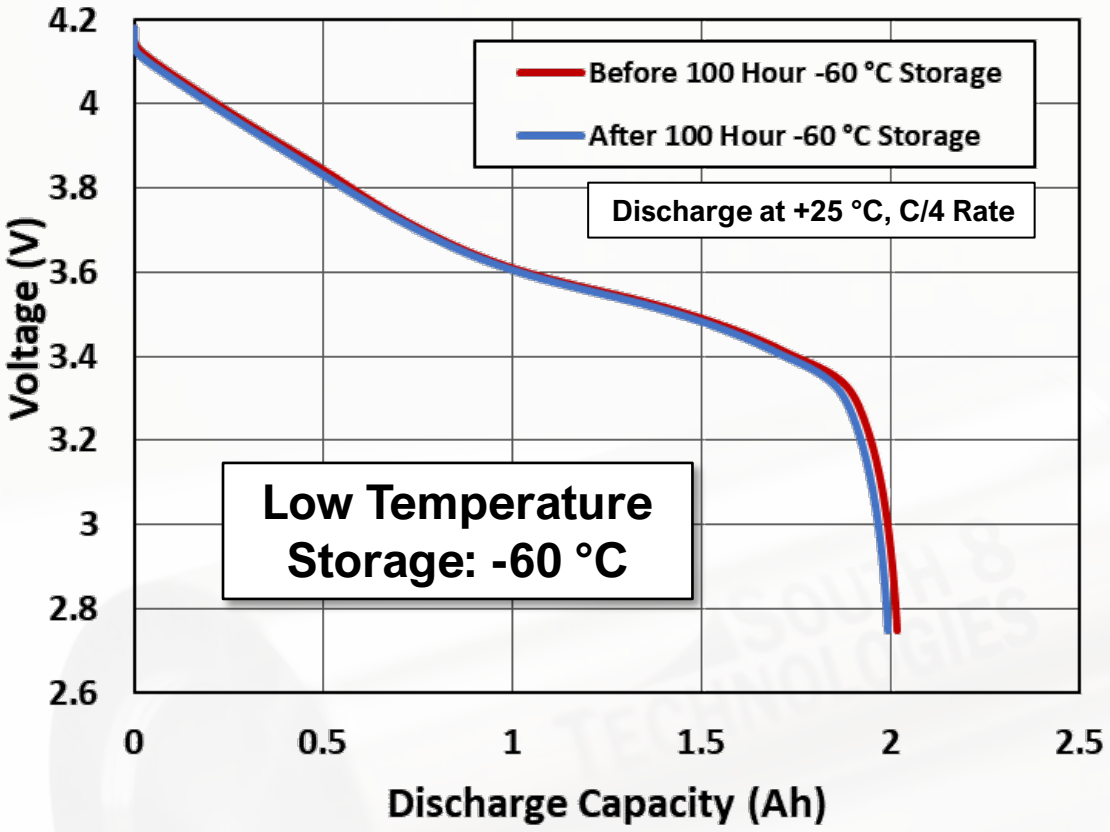

*Excellent electrolyte conductivity across a wide temperature range.*

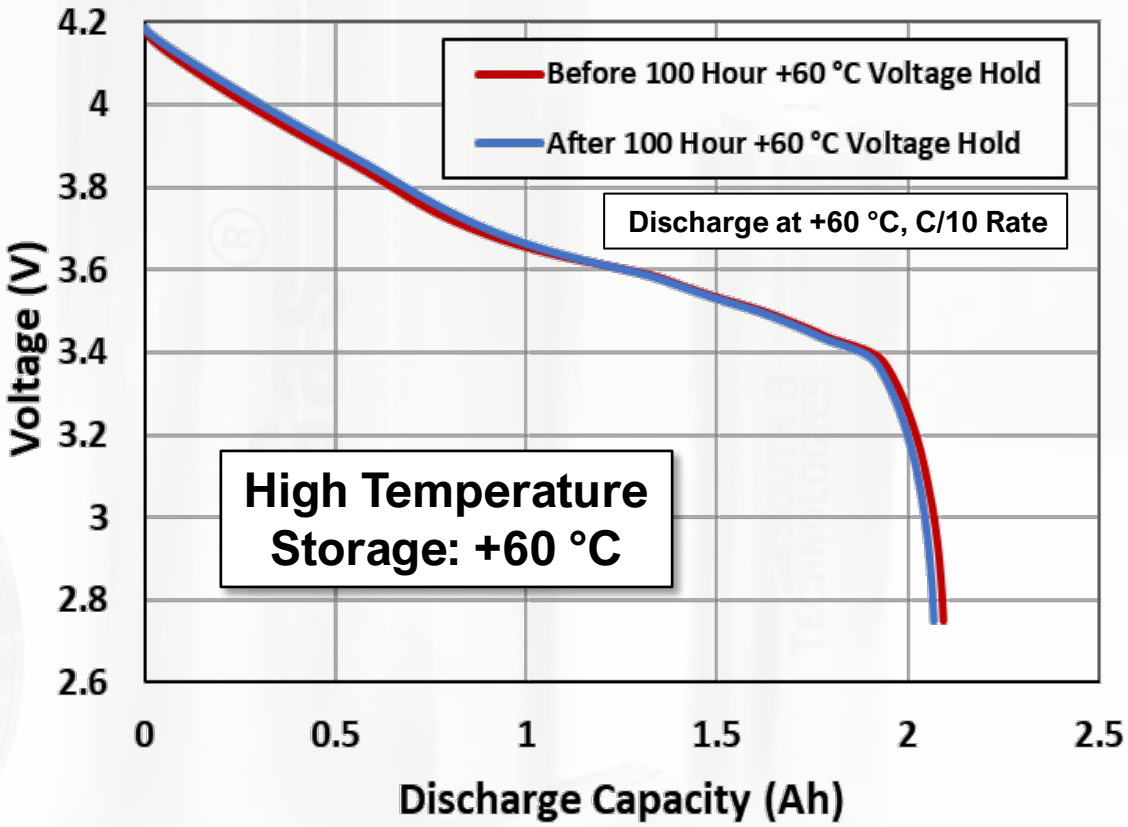



**18650 prototypes demonstrate excellent cycle life.**

- *Stable SEI on graphite anode*
- *First cycle coulombic efficiency ~ 90%*
- *Compatible with all traditional electrodes and binders*

# 18650 Temperature Storage



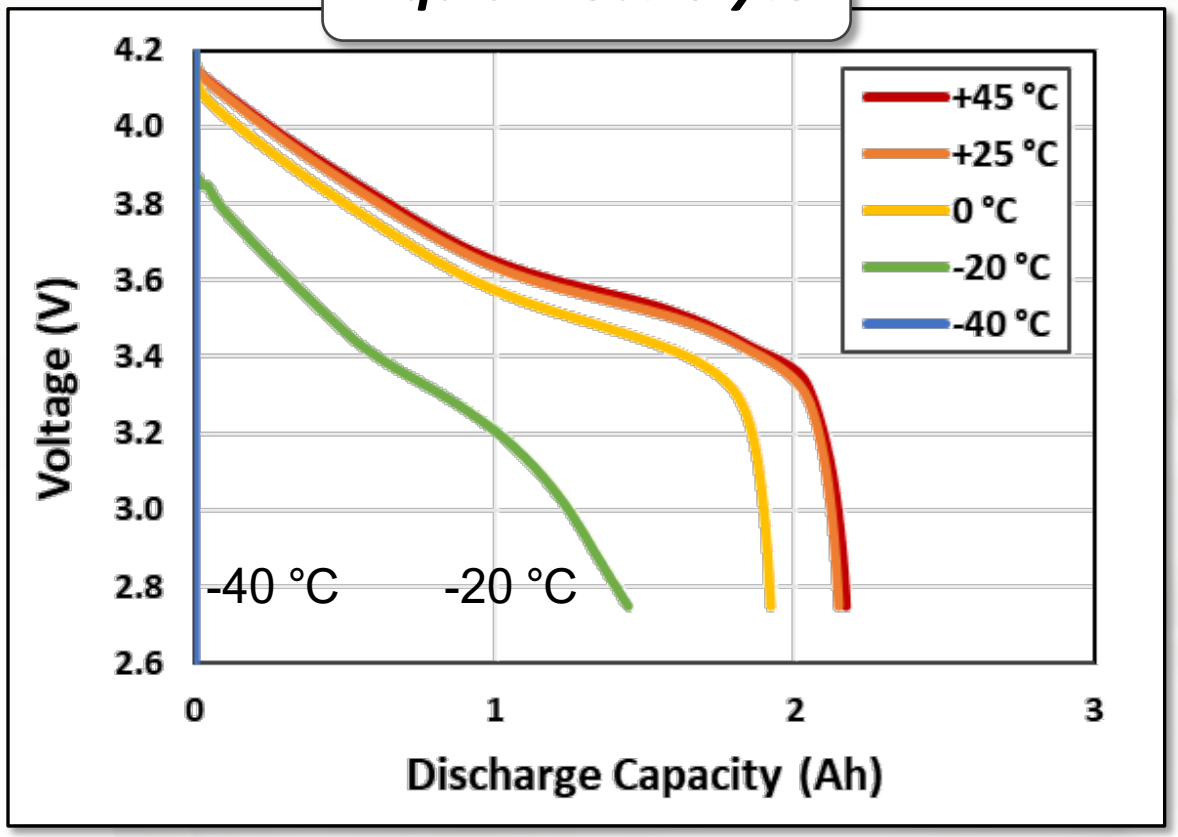




**South 8 LiGas Electrolyte**
**2.2 Ah 18650: NMC622/graphite**
4.2 V float charge, 100 h

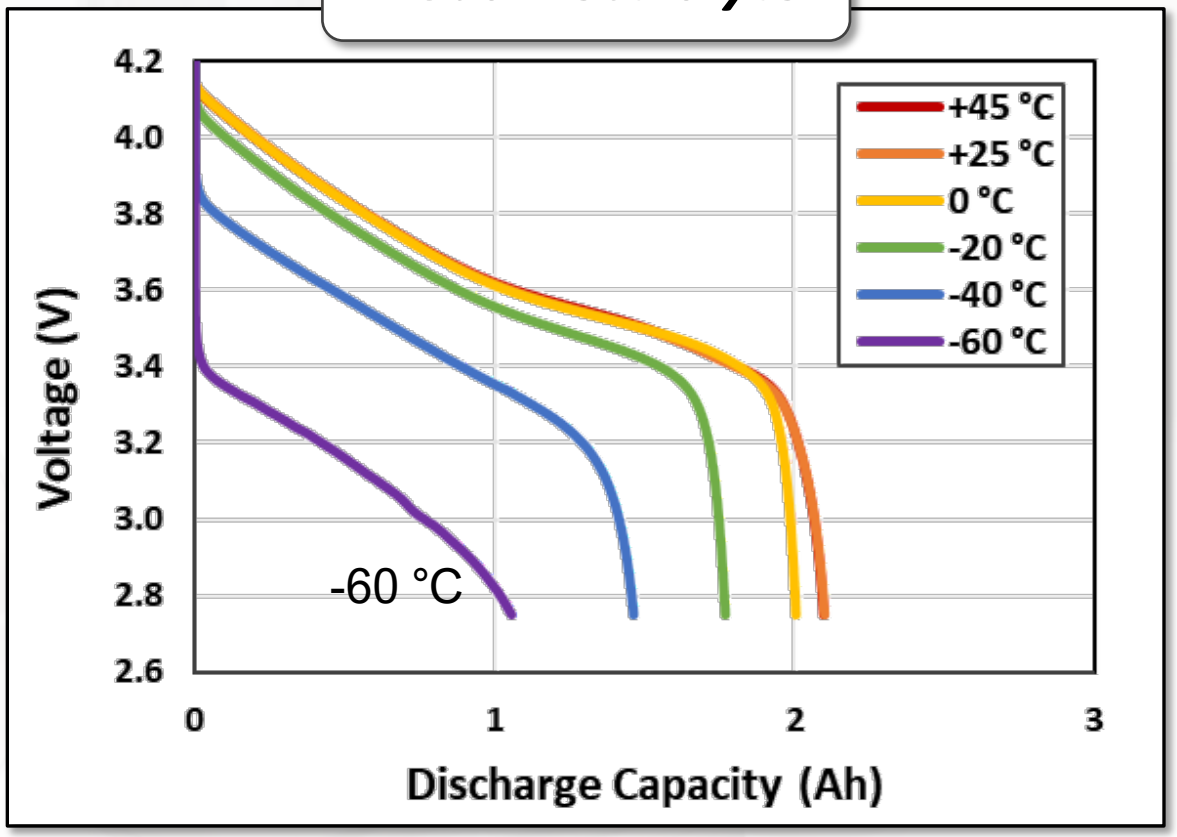
# 18650 at Low Temperature: LiGas vs. Liquid

SOUTH 8 TECHNOLOGIES

***Liquid Electrolyte***

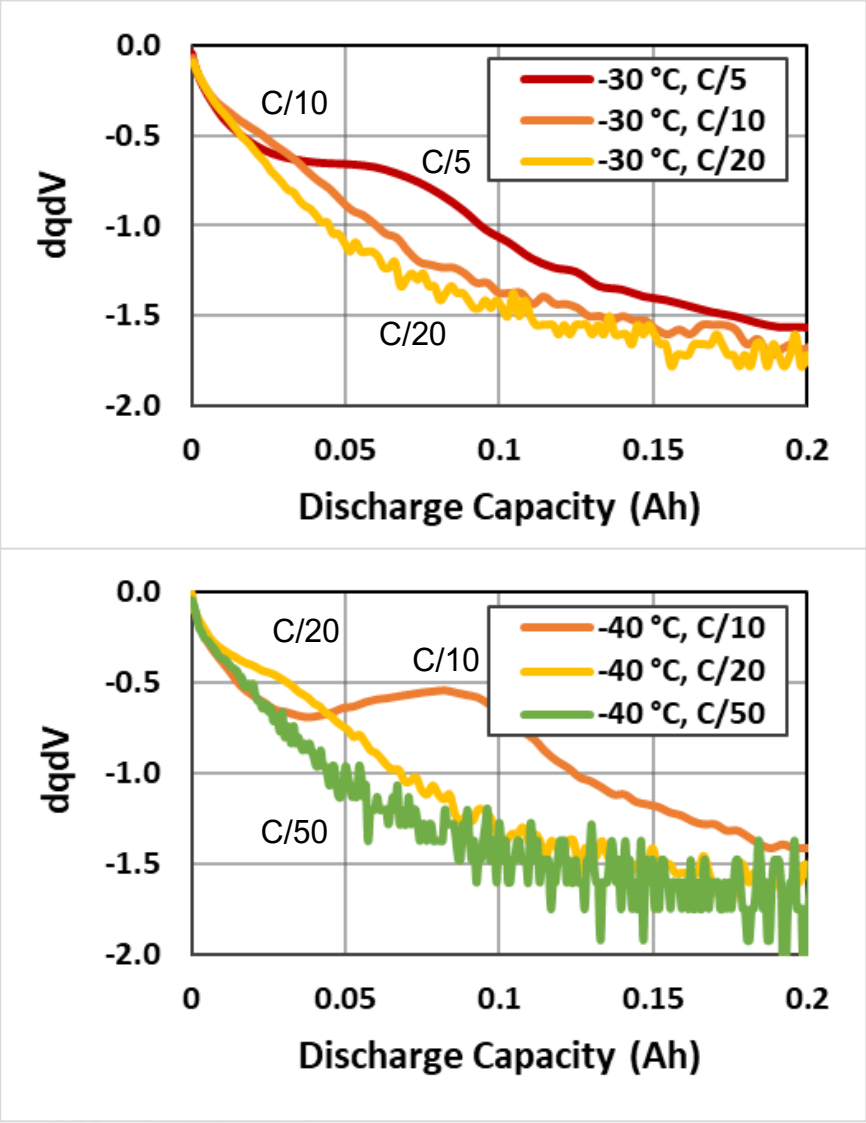



***LiGas Electrolyte***

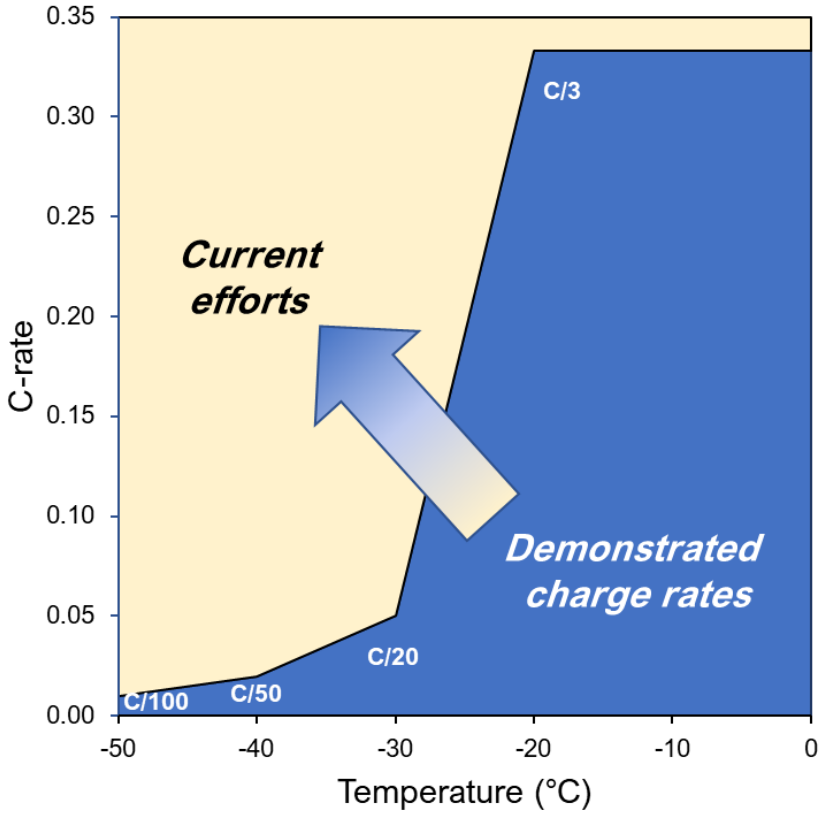



***Charged at +25 ℃***
***C/4 Discharge Rate with Identical 18650 Jelly Rolls***
***2.2 Ah NMC622/Graphite***

# 18650 Low-Temperature Charging

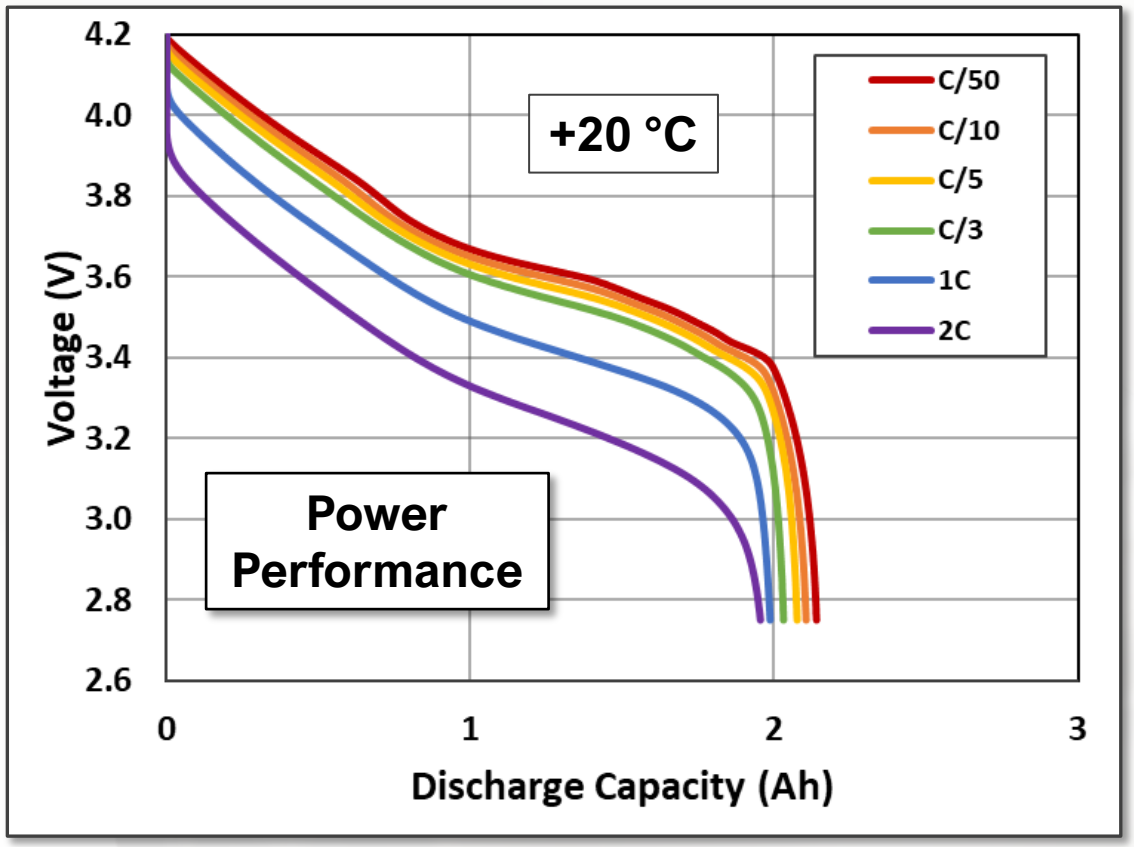


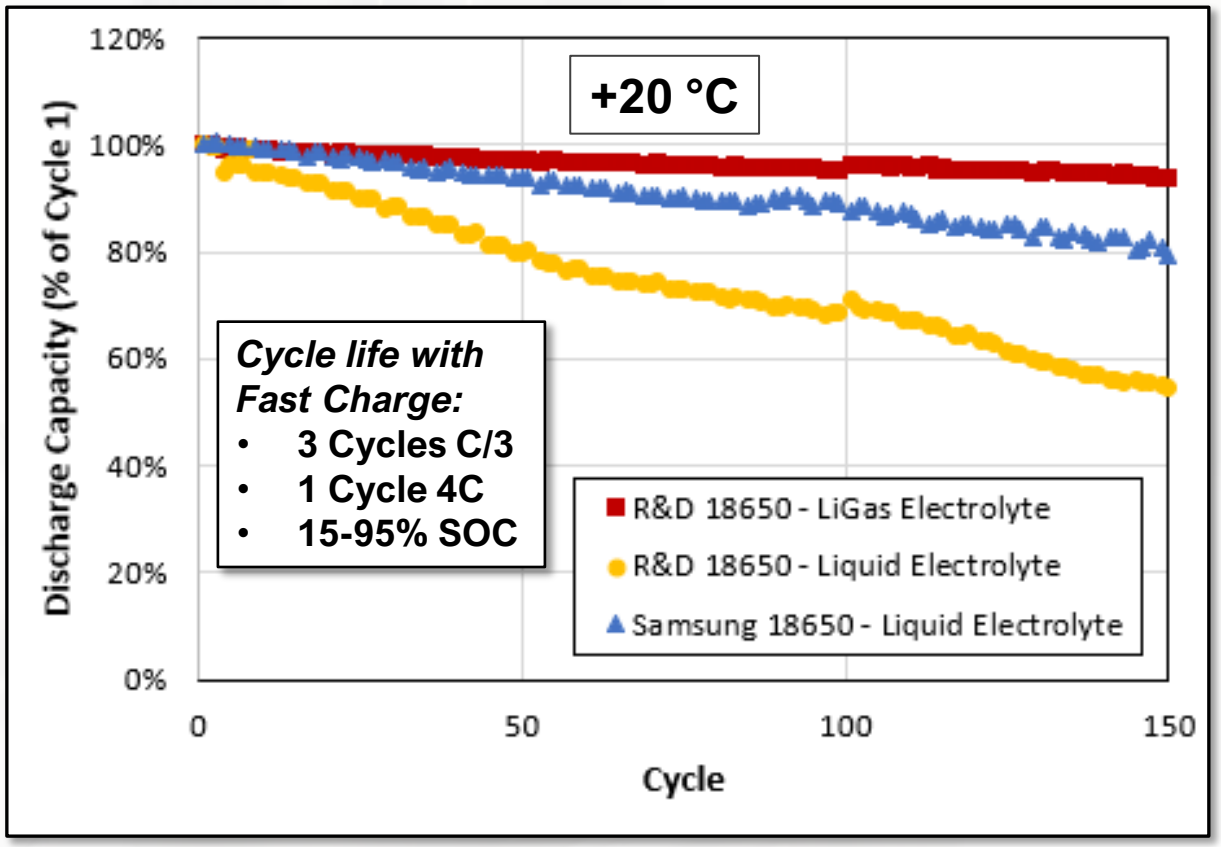

***Demonstrated low-temperature charging without Li plating:***



# 18650 Discharge Power & Fast Charge

SOUTH 8 TECHNOLOGIES

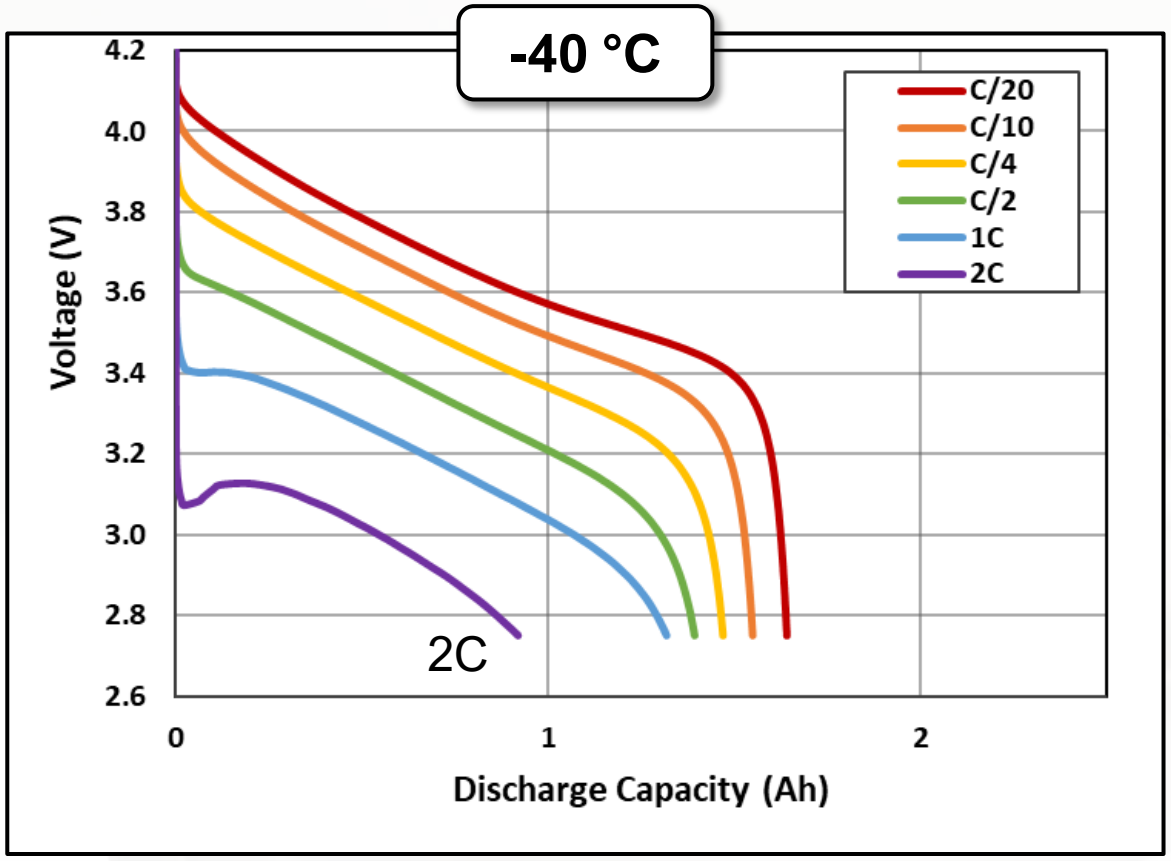


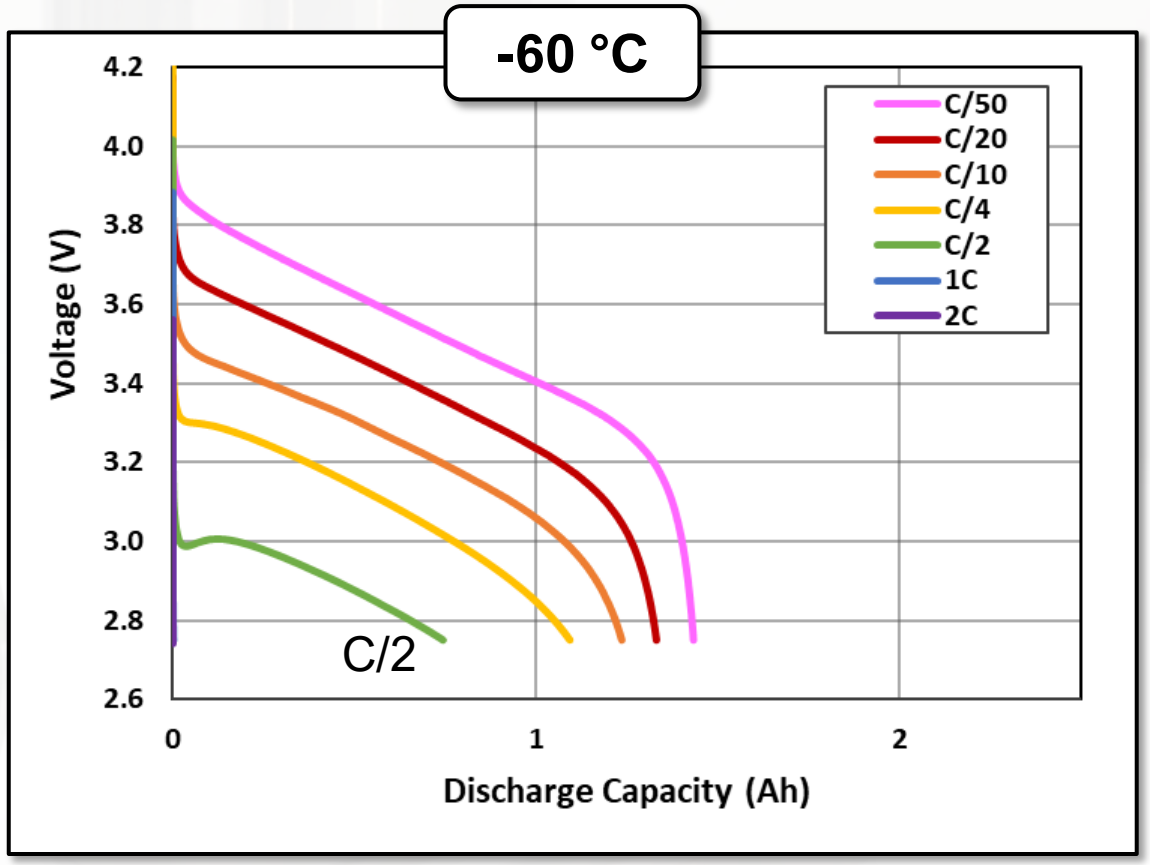




***LiGas electrolyte has high conductivity and produces favorable SEI***

# 18650 LiGas Low-Temperature Rate Performance

SOUTH 8 TECHNOLOGIES

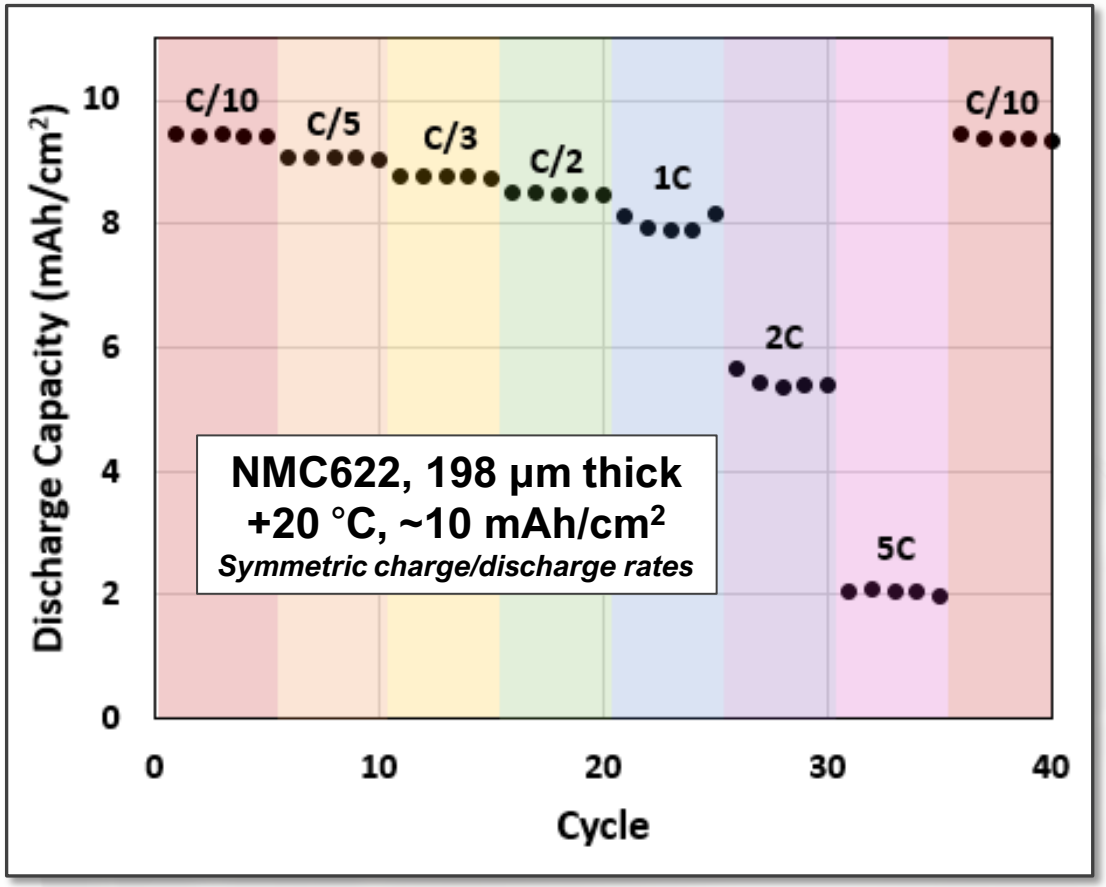


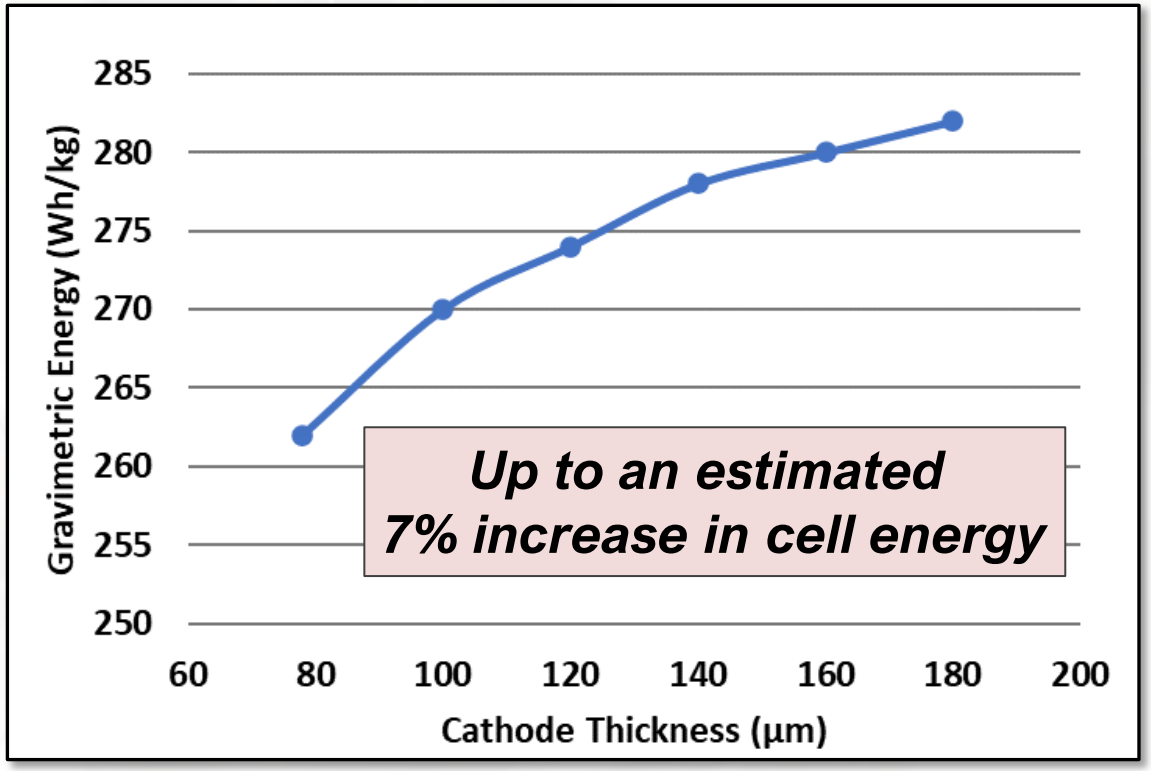




**South 8 LiGas Electrolyte**
**2.2 Ah 18650: NMC622/graphite**
*Each discharge followed a C/4 CC-CV charge at +25 °C*

# Enabling Thick Electrodes Increases Energy

SOUTH 8 TECHNOLOGIES

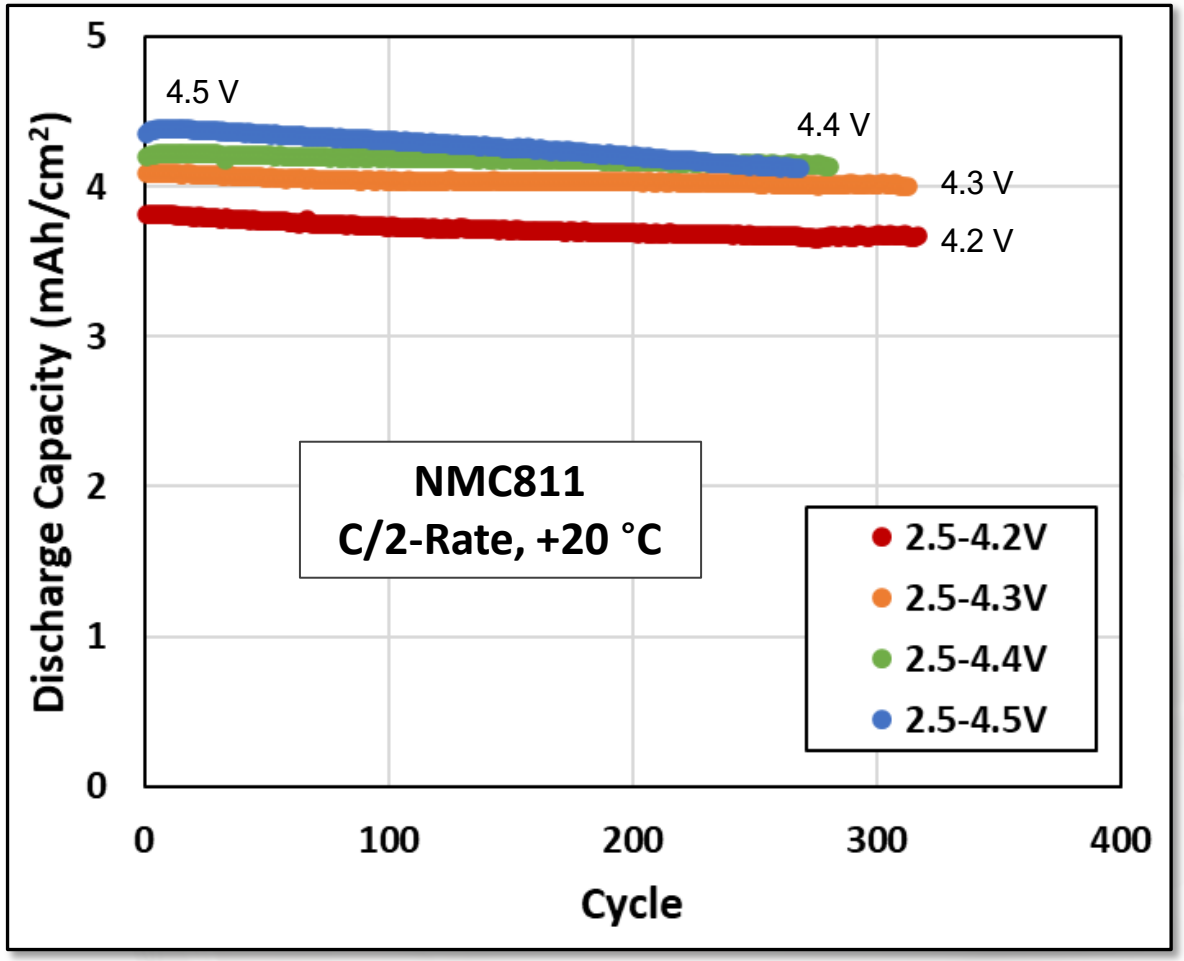


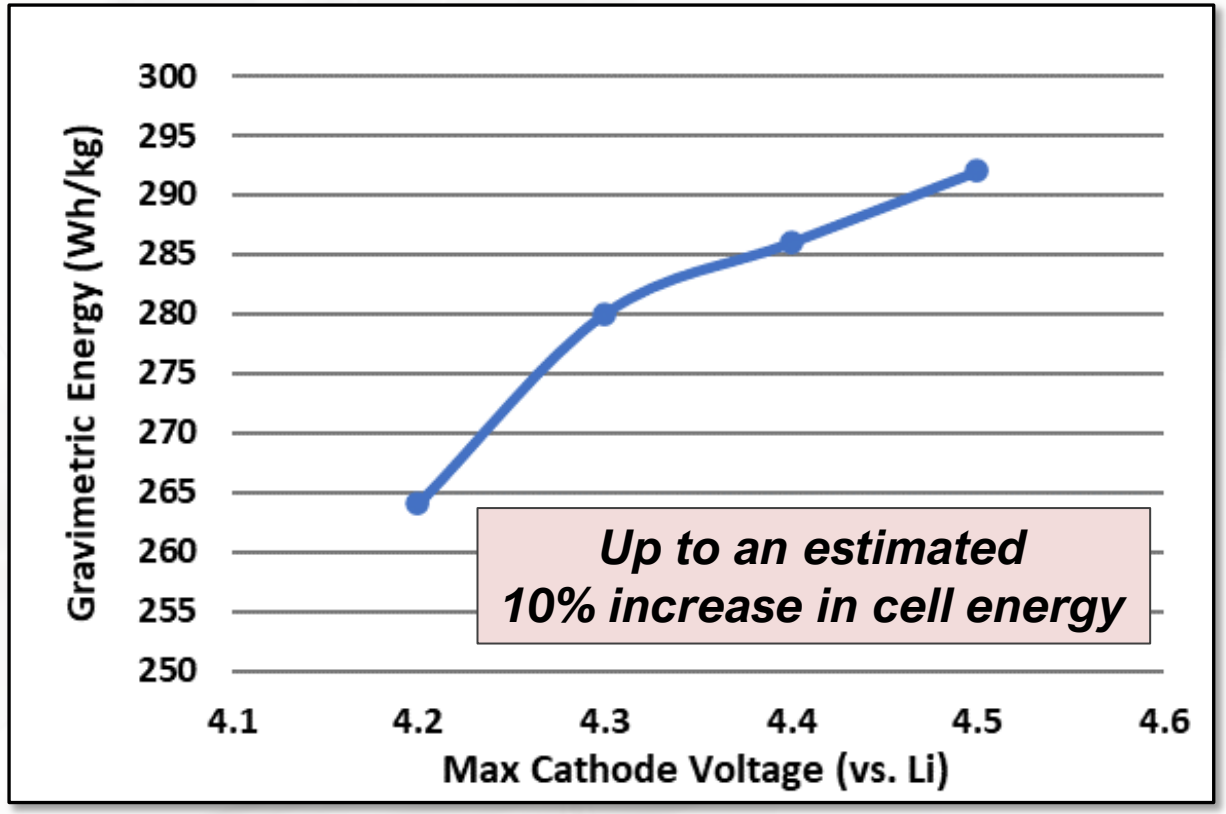




***LiGas*** **electrolyte's pressure results in rapid and efficient wetting, even with very thick electrodes**

# High Voltage: High-Ni and Co-free Cathodes

SOUTH 8 TECHNOLOGIES



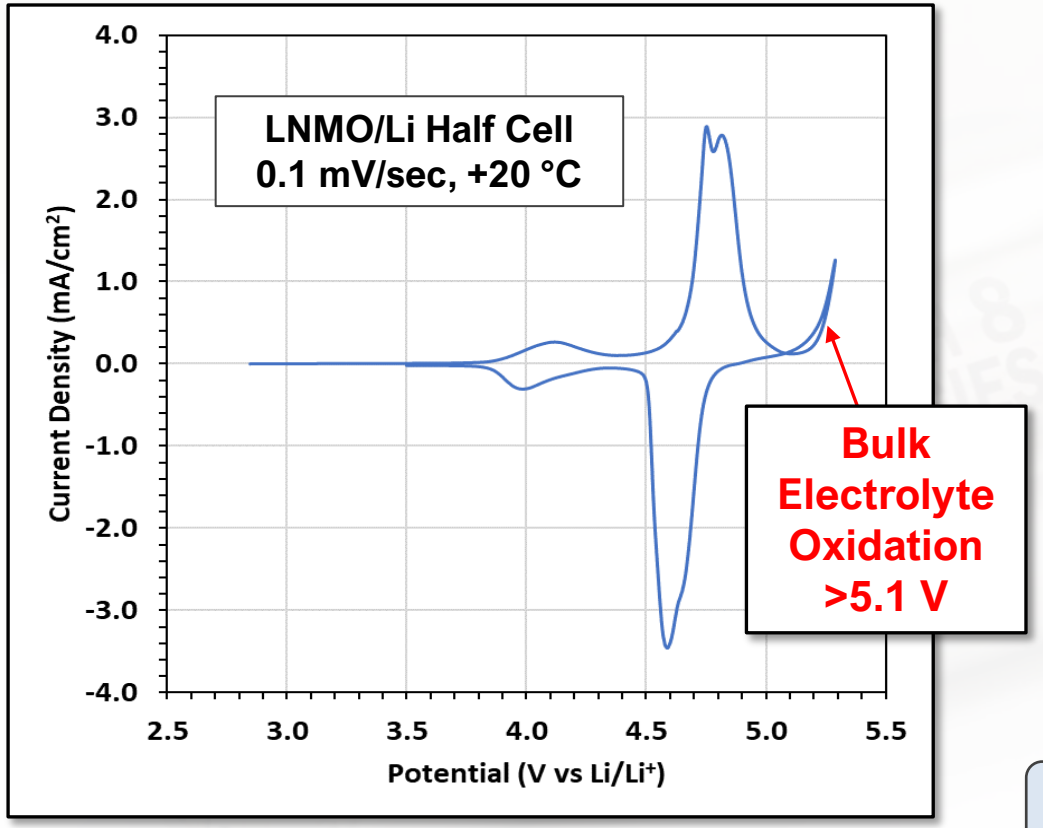



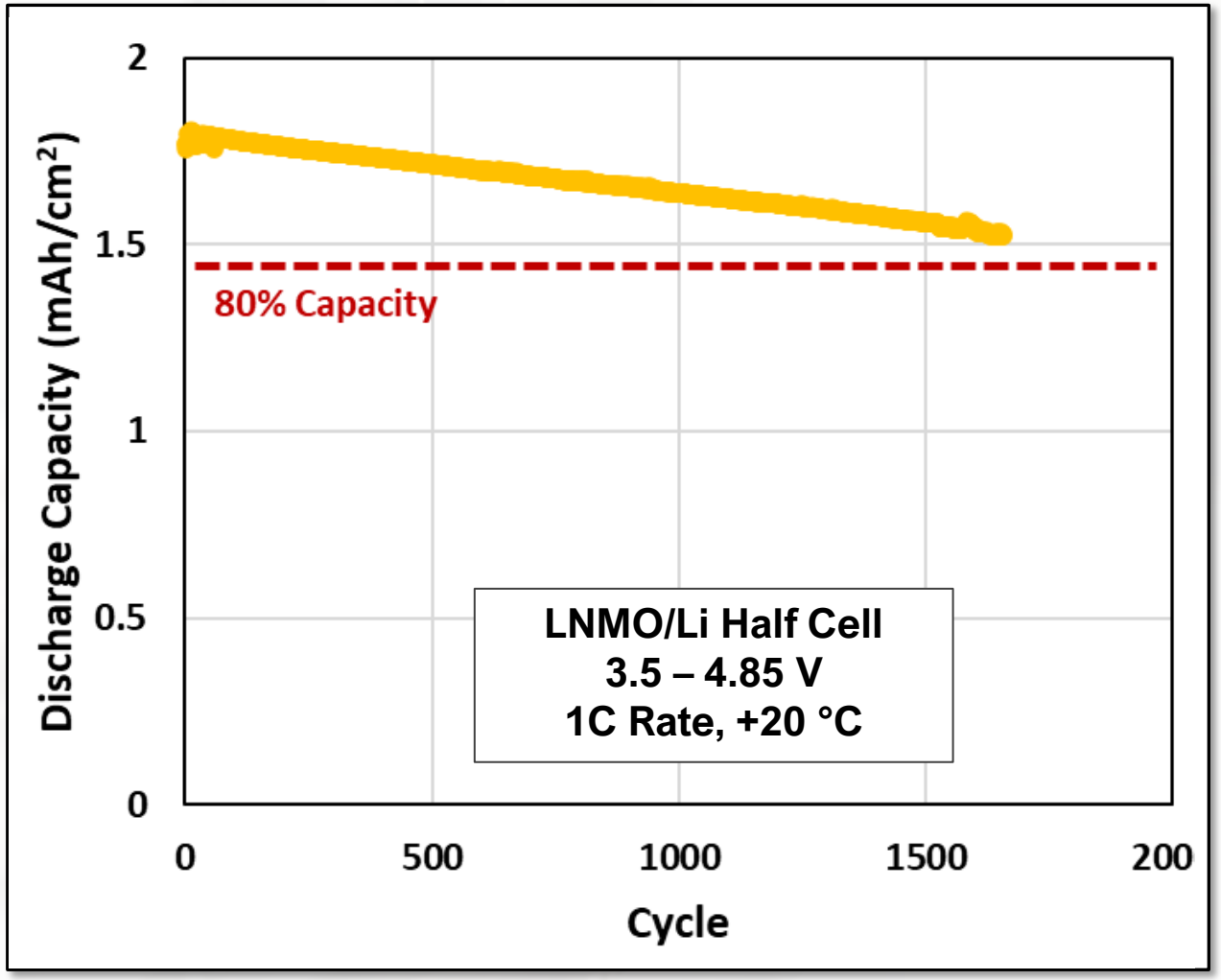

**LiGas electrolyte forms an effective CEI and Al passivation layer**

# High Voltage: High-Ni and Co-free Cathodes

SOUTH 8 TECHNOLOGIES

**Estimated 10~15% $/kWh Reduction**
**Cobalt-Free LNMO Cathode**




***Excellent cycling stability with 4.85 V cathode***

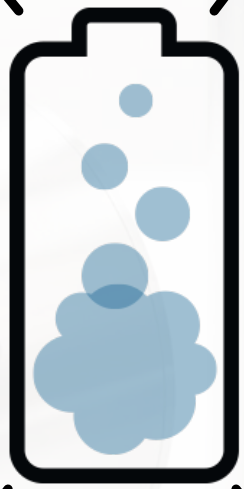
# LiGas Advantages

SOUTH 8 TECHNOLOGIES

**Improved Safety**
Non-flammable, non-toxic *LiGas* electrolytes

**Cost-Effective**
Faster manufacturing, high voltage, thick electrodes, safer cells.

**Fast Charge**
High electrolyte conductivity & ideal SEI enables <15 min fast-charge



**All-Weather Resilience**
-60 to +60 °C Operation

**Material Compatibility**
Fully compatible with all common cell electrodes, separators, cans

**Increased Energy**
Thicker electrodes, more efficient battery system integration

**Improved Recyclability**
Safer handling of dry cells, no longer need hazardous shipping

**Faster Manufacturing**
Electrolyte injection & wetting times reduced from hours to minutes.

# Liquefied Gas Electrolytes

## for Next-Generation Lithium Batteries


***Thank you!!***

info@south8technologies.com
www.south8technologies.com