

Large Format $\text{Li}_4\text{Ti}_5\text{O}_{12}$ Lithium-Ion Batteries

Performance and Applications

Bob Misback
Altairnano, Inc.

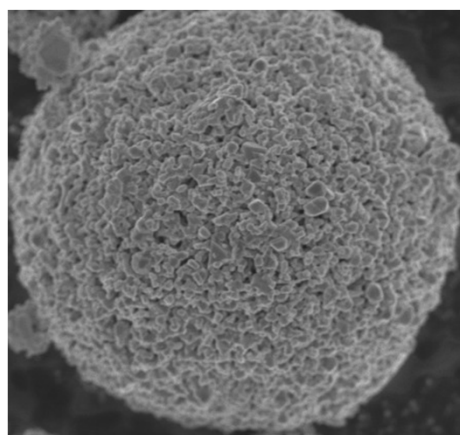
Creating A Better Lithium-Ion Battery

- Altairnano designs and manufactures advanced lithium-ion batteries and systems using its proprietary lithium titanate nanotechnology
- Our technology provides unique:
 - Battery life
 - Safety
 - High charge and discharge rates
 - Lowest Life Cycle Cost
- Our mission is to become the leading global supplier of energy storage systems for clean, efficient power and energy management.

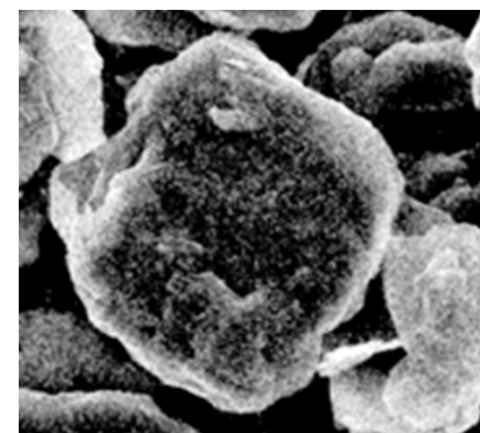


Lithium-Titanate Nanotechnology Solves the Difficult Lithium-ion Battery Challenges

- Safer
- Longer Cycle Life
- Higher Power
- Wider Temperature Operating Range
- Higher Charge and Discharge Rates



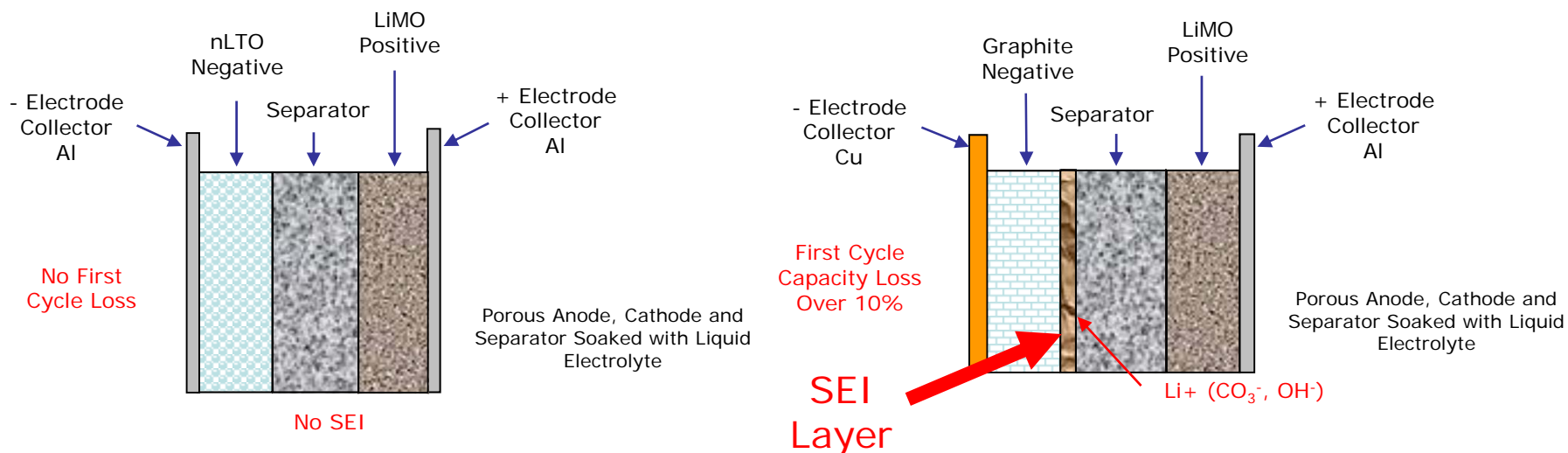
10 microns
nano Lithium-titanate
particle with 0.03-0.06
micron crystallites fused
together in Altair's nano
manufacturing process



10 microns
Traditional Graphite
crystal

The difference begins with the material properties – nLTO has 1000 times the surface areas of Graphite per volume, but can utilize standard manufacturing battery cell manufacturing processes

Electro-chemical Stability Improves Temperature Range, Safety, and Cycle Life



Nano-Lithium Titanate

The Altairnano Advantages:

- Low reactivity with electrolyte eliminates Solid Electrolyte Interface (SEI) layer creating improved thermal stability and safety
- Lithium-titanate capable of absorbing oxygen molecules at very high temperatures from cathode degradation reducing risk of thermal runaway increasing safety
- Lithium-titanate chemistry eliminates creation of dendrite formation reducing risk of internal cell short circuits

Traditional Graphite

- Based on DSC measurement, K. Amine et al., have shown that heat generation from lithiated graphite is nearly an order of magnitude higher than that from lithiated LTO.

Journal of The Electrochemical Society, **154** (12) A1083-A1087 (2007)

I. Belharouak,^{a,*} Y.-K. Sun,^b W. Lu,^a and K. Amine^{a,*}

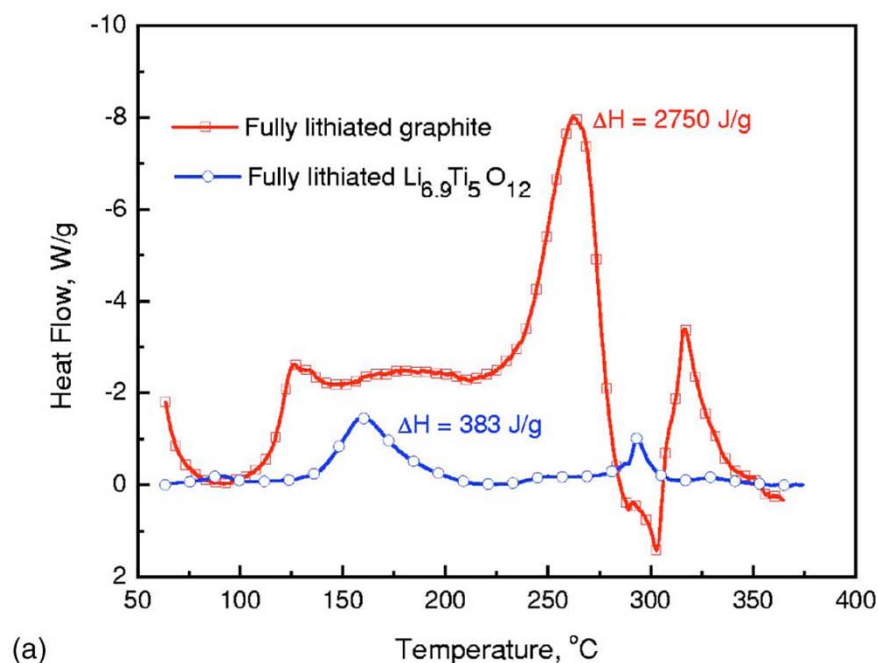
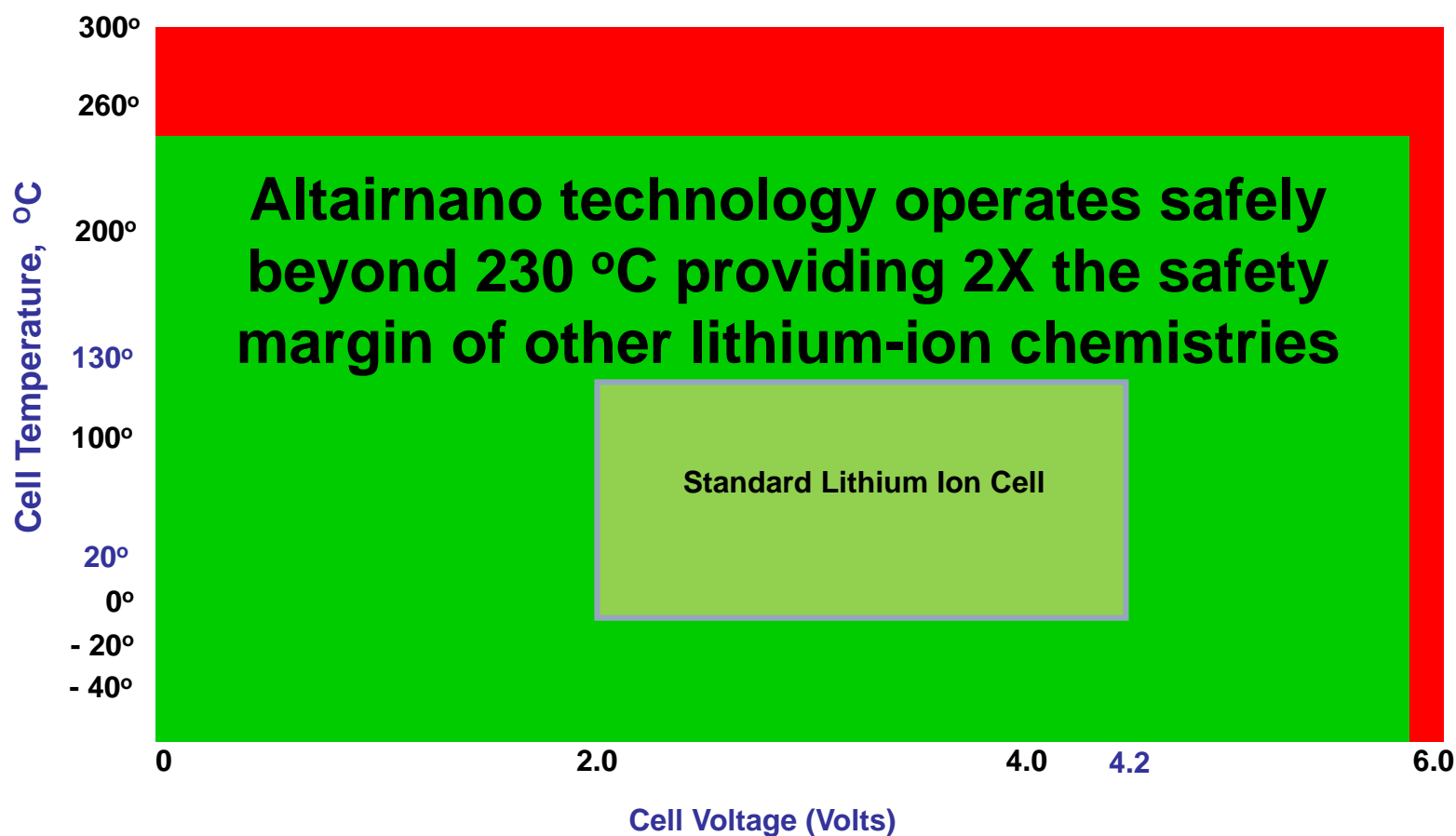


Figure 5. (Color online) (a) DSC curves of fully lithiated graphite and fully lithiated Li₄Ti₅O₁₂. (b) Corresponding accumulated heat curves.

Wider Temperature and Voltage Ranges Provides Greater Safety Margin



The Result: At 240 °C, Altairnano Provides Unmatched Safety Performance

Before

After

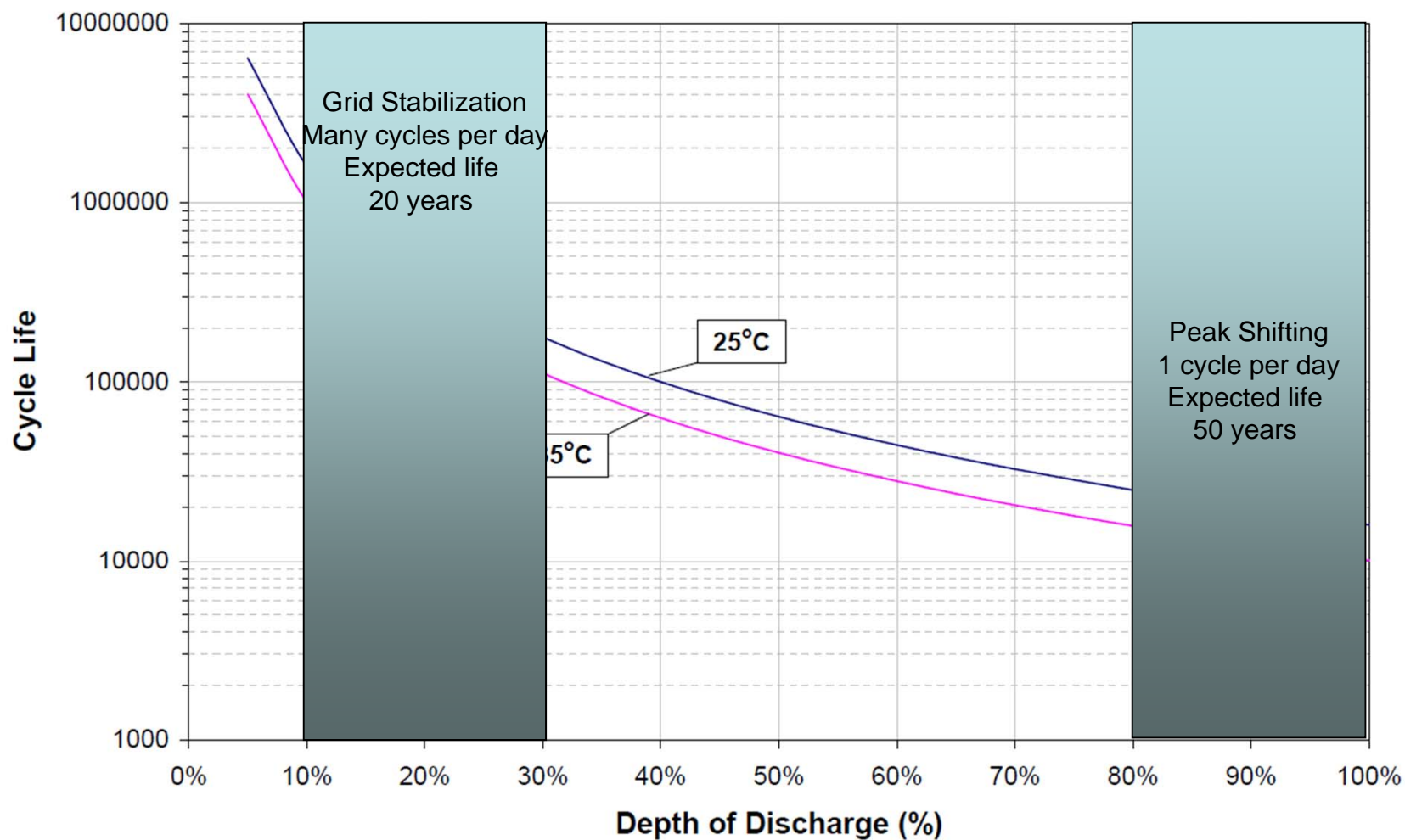
Traditional lithium-ion battery experiences catastrophic failure at 160 °C



Altairnano battery remains intact with no thermal event at 240 °C

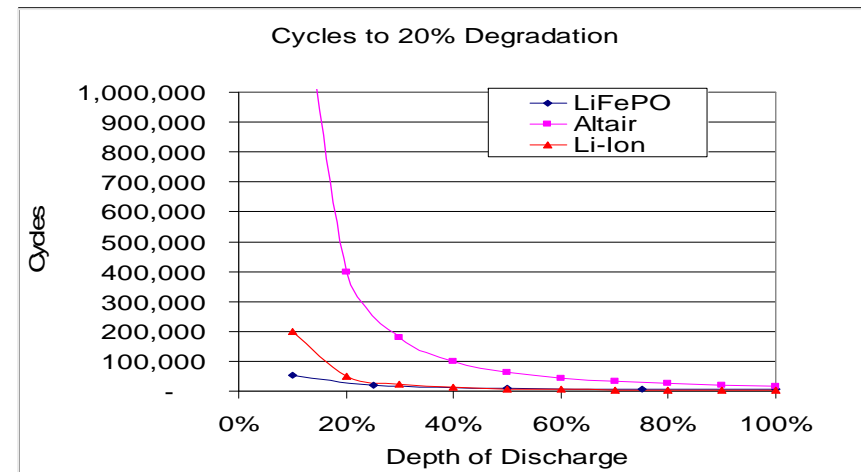
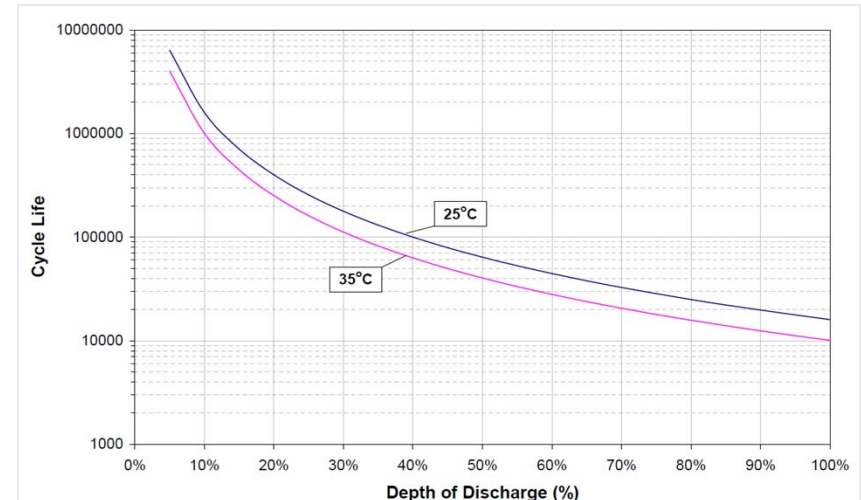


Altairnano Lithium Titanate Battery Cycle Life to 80% Capacity

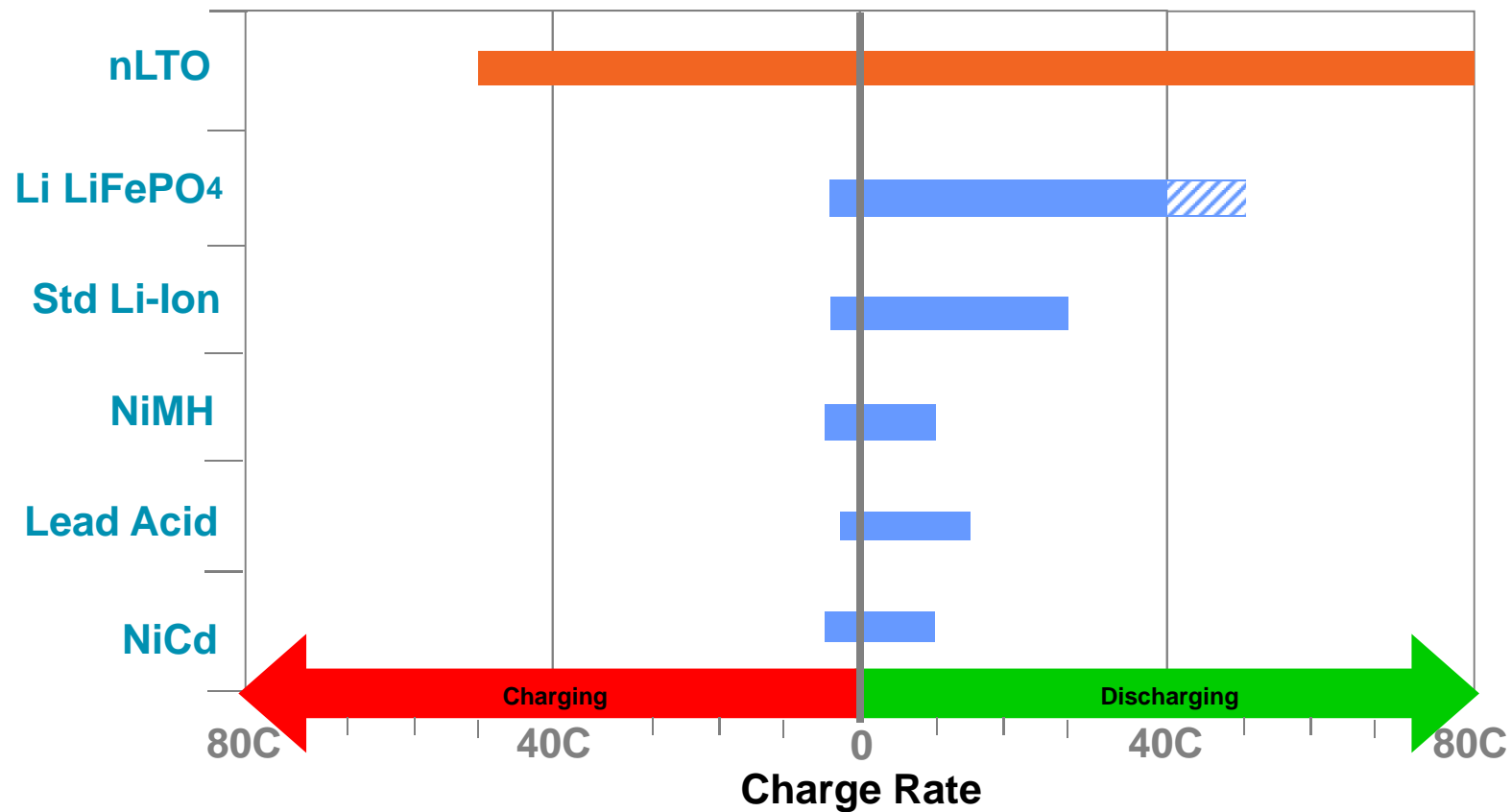


Long Cycle Life Means Better Economics

- At 100% depth-of-discharge, Altairnano technology provides 3-6 times more cycle life than other Li-Ion
- At low depth-of-discharge cycles, over 1 million cycles and up to 100X more life than other Li-Ion
- Long cycle life drives down the cost of ownership in demanding applications



Altairnano Lithium-titanate charges 10 times faster than competing technologies



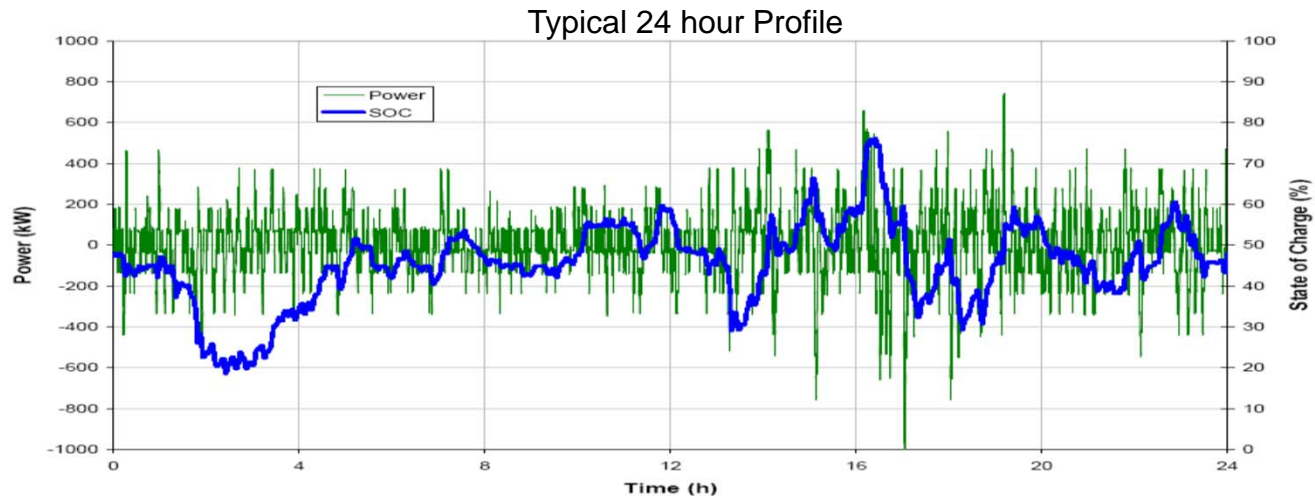
Altairnano's ESS is the Only Advanced Li-Ion Batteries in Continuous Commercial Operation for Frequency Regulation

Two 1 MW Field Test Units installed at Indianapolis P&L May 2008
Testing Complete: June 2008
Qualified for Commercial Operation in PJM: November 2008
Running 24/7: May 2009



Technical Capabilities Validated in Independent Testing by KEMA

Commercial Validation from First Year of Commercial Operation in Grid Stabilization



- Reliable operation and interaction with the Grid
- Capacity Factor over 90%, generating revenues in line with plan
- Less than one percent energy capacity degradation and no significant power capacity degradation
- Expected to maintain rated power and energy capacity for over twenty years without battery replacements or upgrades

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