

DUTY CYCLE & BATTERY LIFE

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ESIG

2019 Fall Technical Workshop

October 28 – 30, 2019

Charlotte, NC



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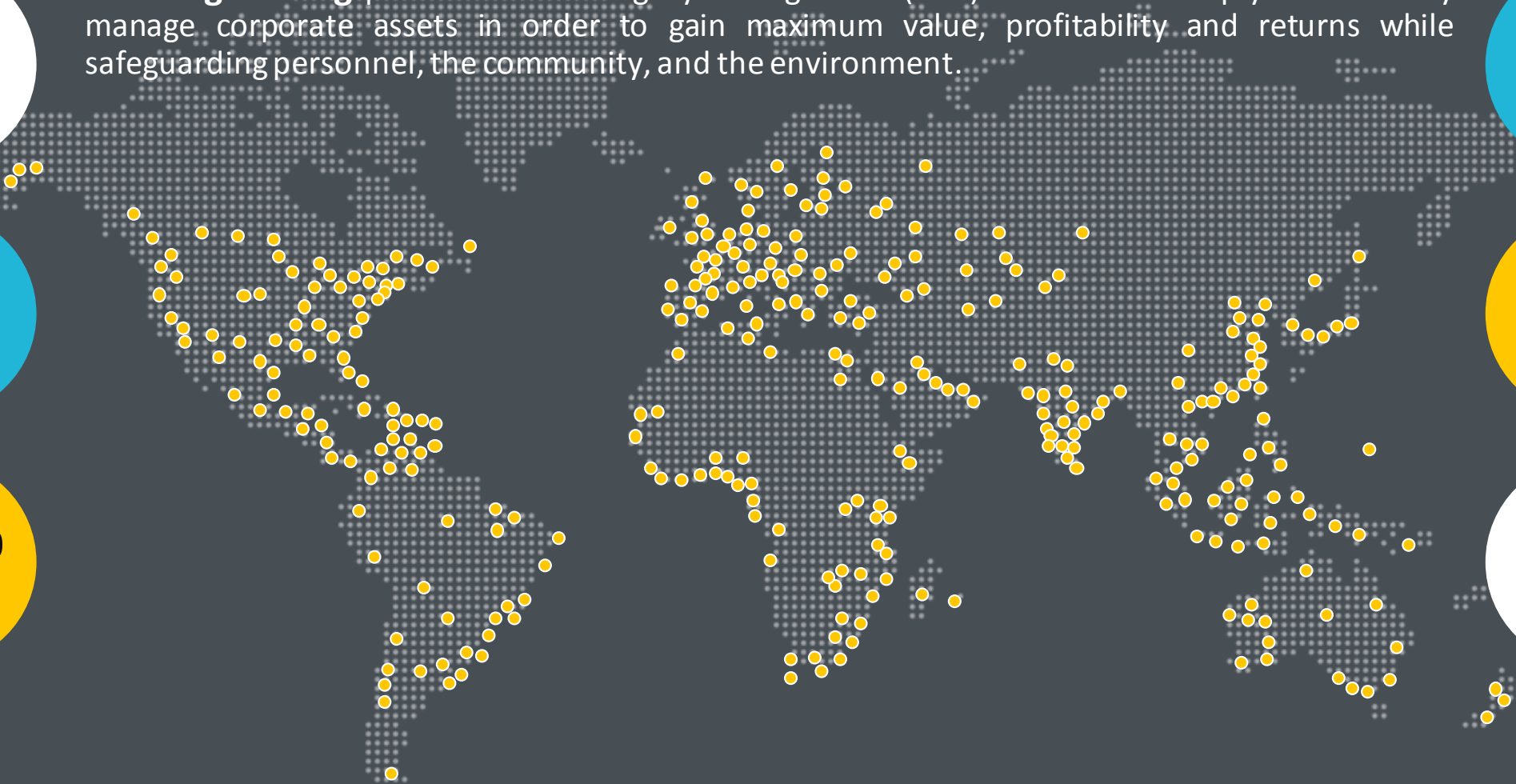
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BATTERY BASICS

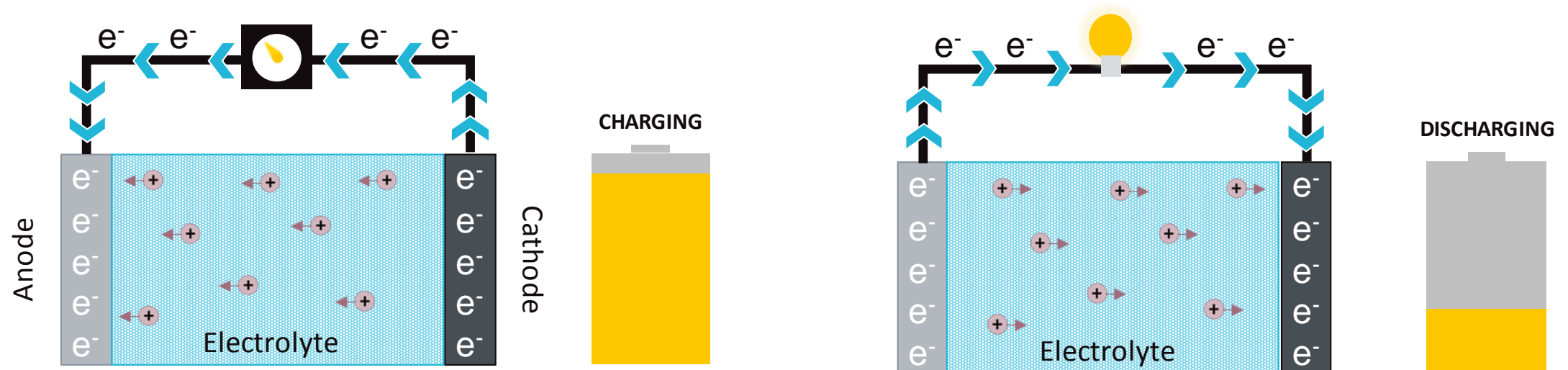


All batteries are composed of:

- Cathode
- Anode
- Electrolyte

Electrodes are separated and electrolyte facilitates ion transport between electrodes

Electrons travel through the outer circuit to do work



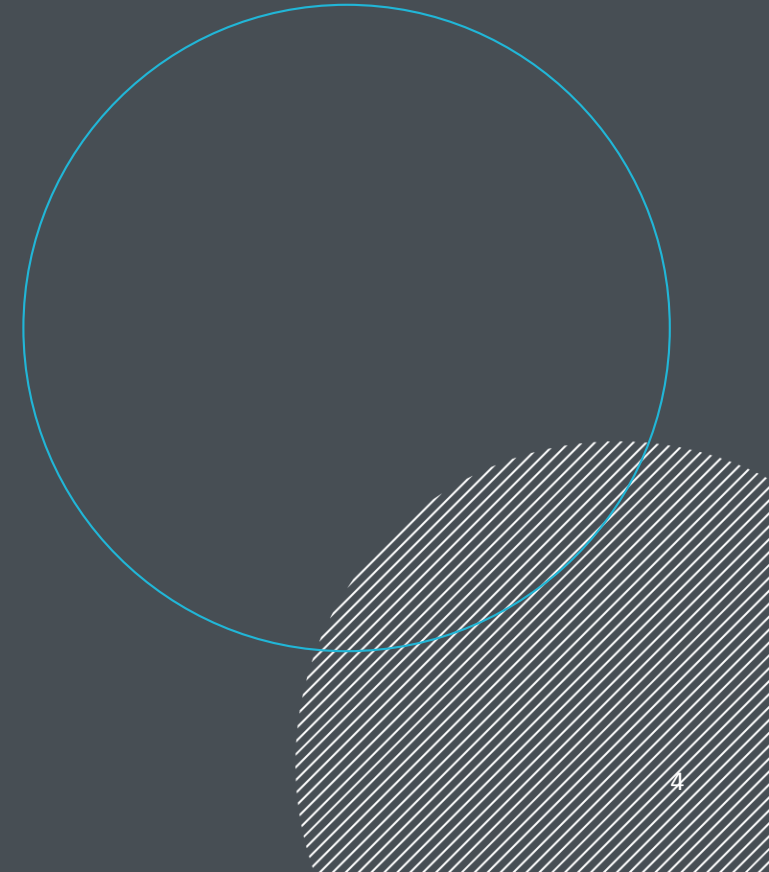


Performance is dependent on battery chemistry

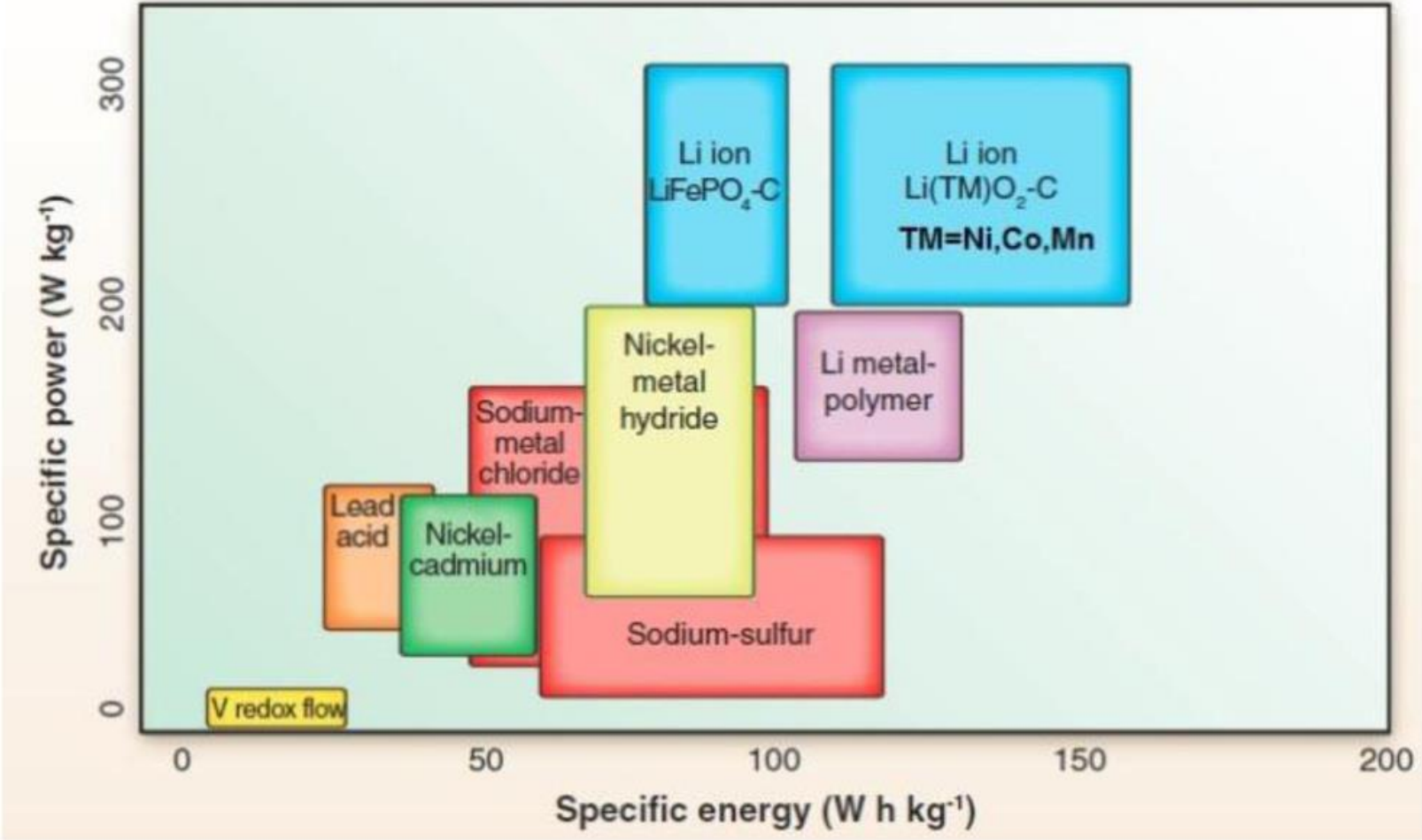
- Energy required to create and break chemical bonds will dictate electrical potential
- Amount of exposed electrode surface area will dictate battery energy capacity
- Crystal structure of electrode materials will dictate charge capability
- The type of electrolyte used will affect energy capacity, charge capability, and dictate temperature constraints

Different battery types will have different expected –

- Energy capacities
- Rate capabilities
- Life cycles
- Efficiencies



BATTERY BASICS | RAGONE PLOT

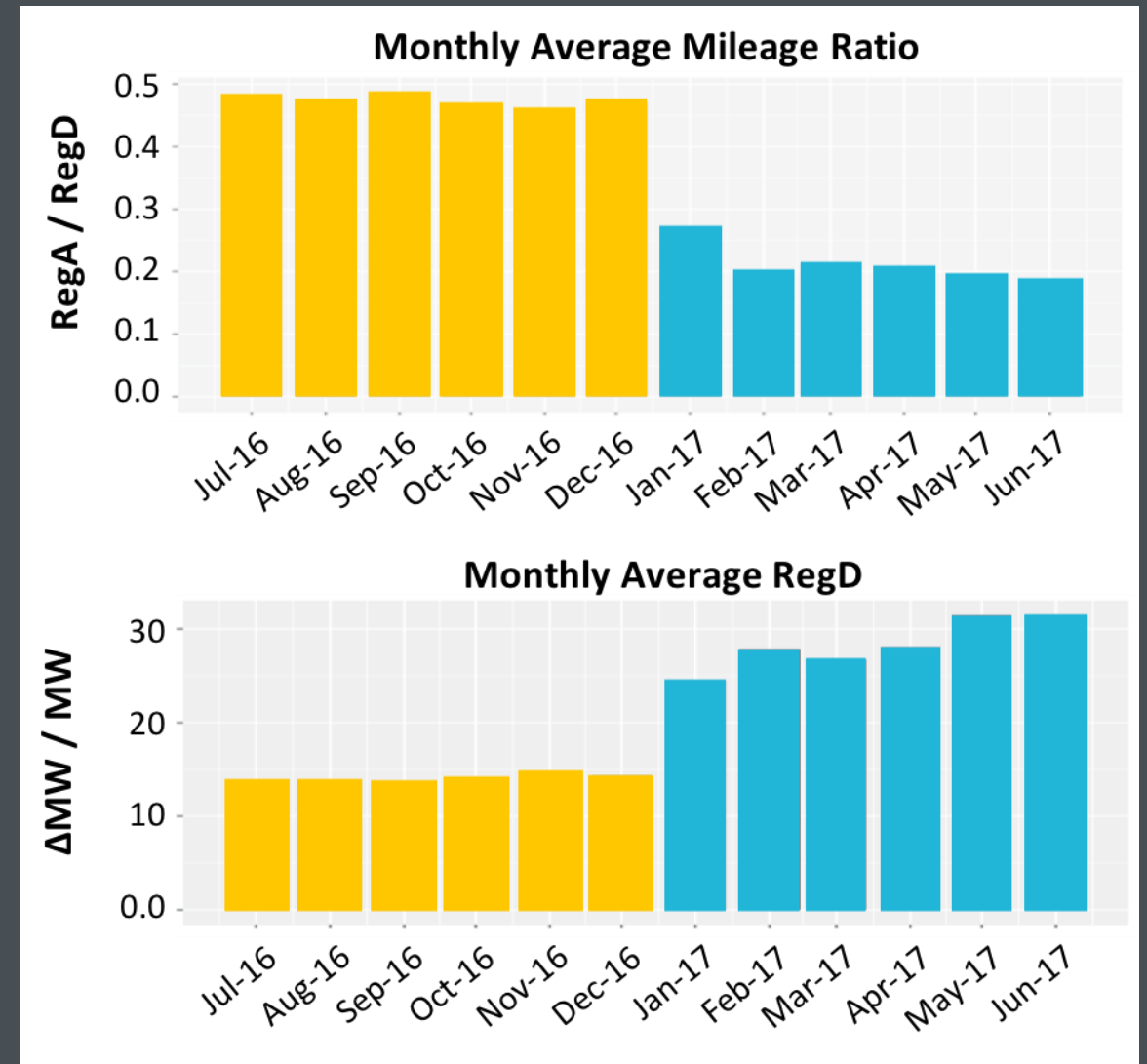


Yang, M. & Hou, J. "Membranes in Lithium Ion Batteries," *membranes* (2), 2012.

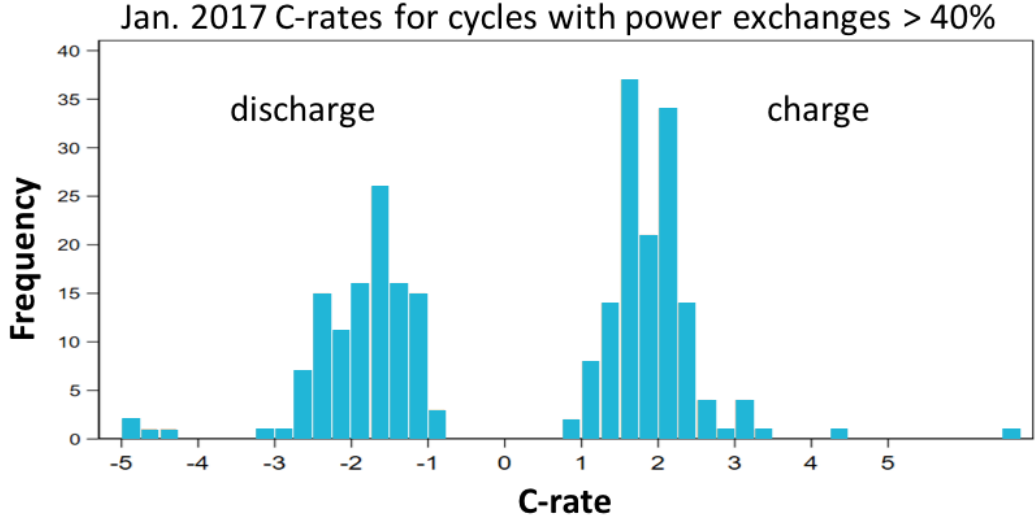
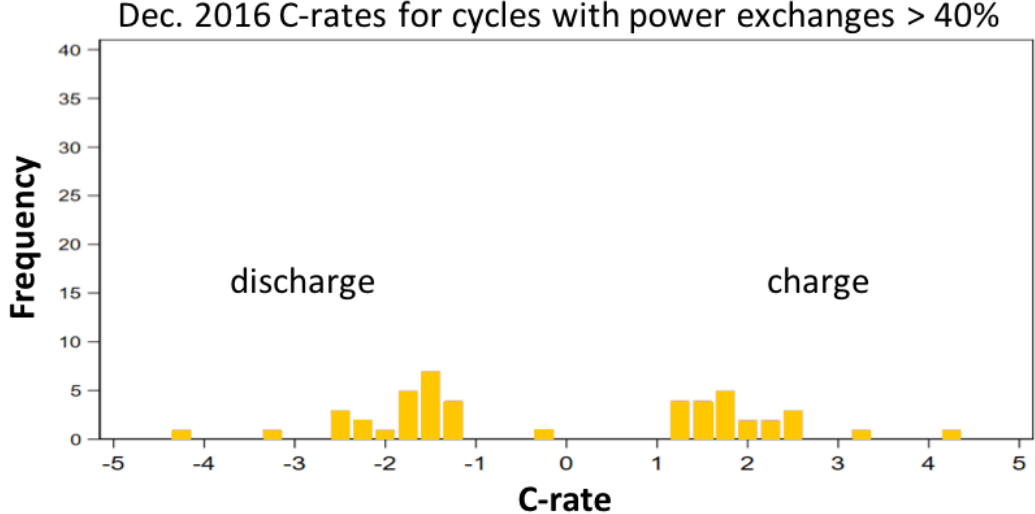
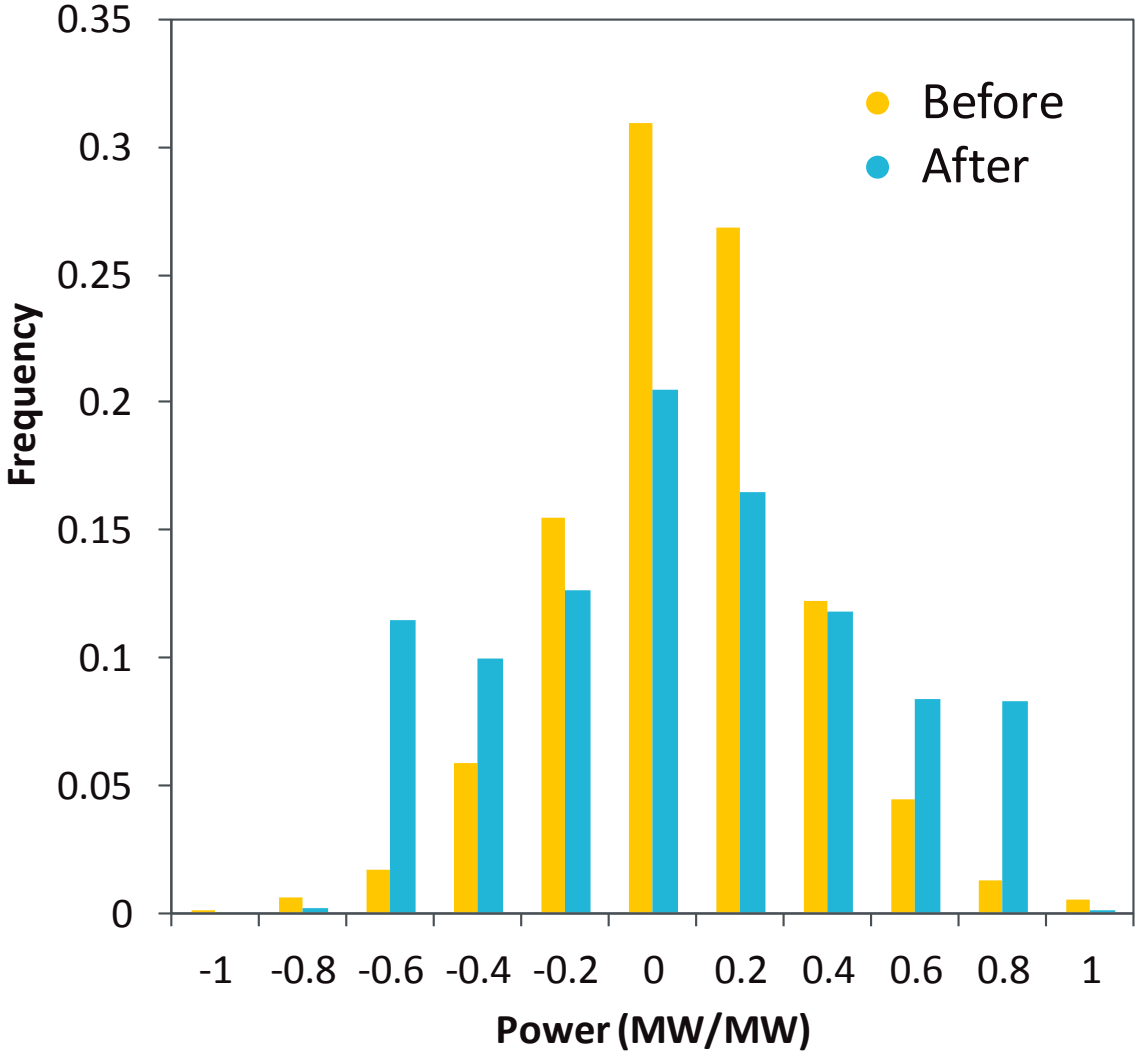
INTRODUCTION



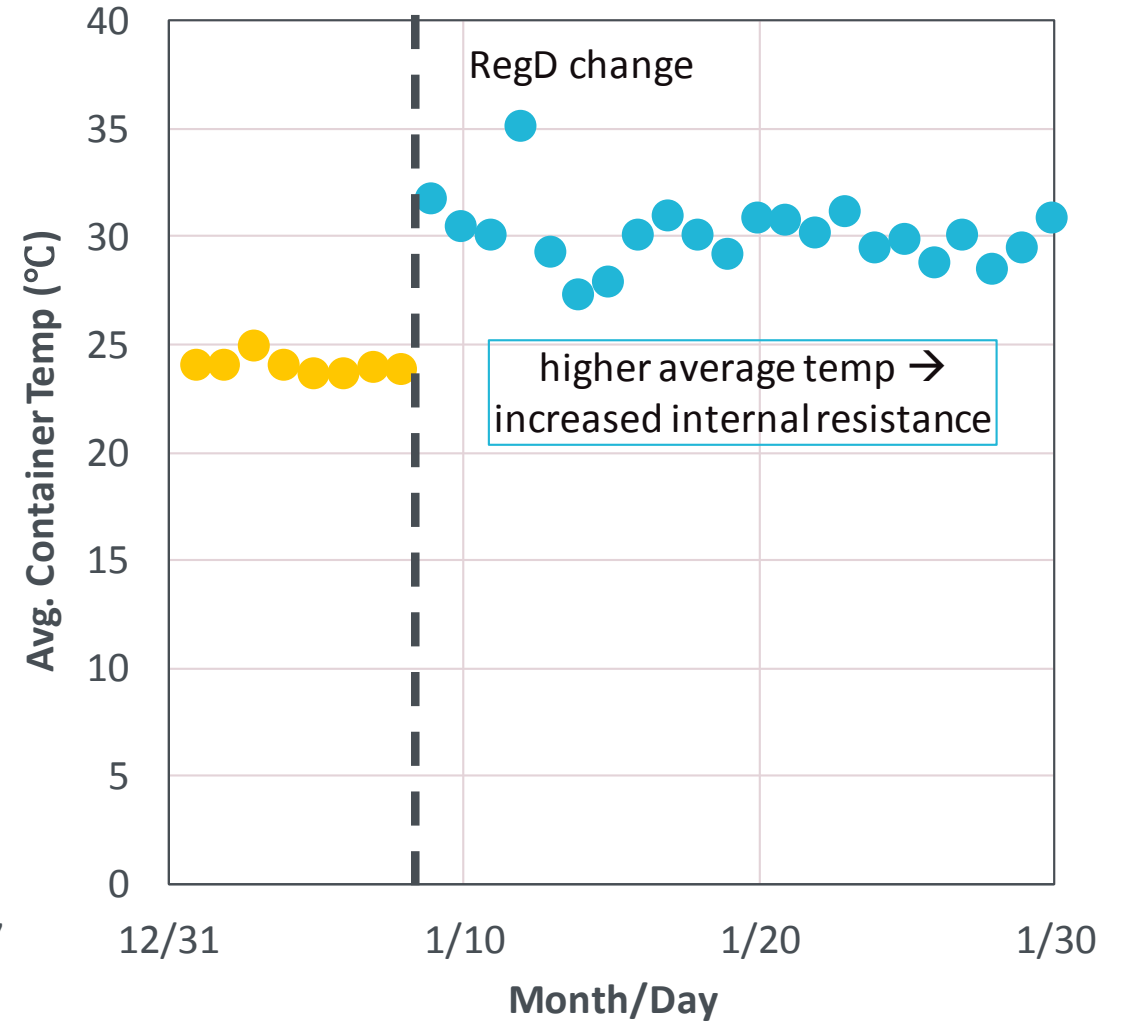
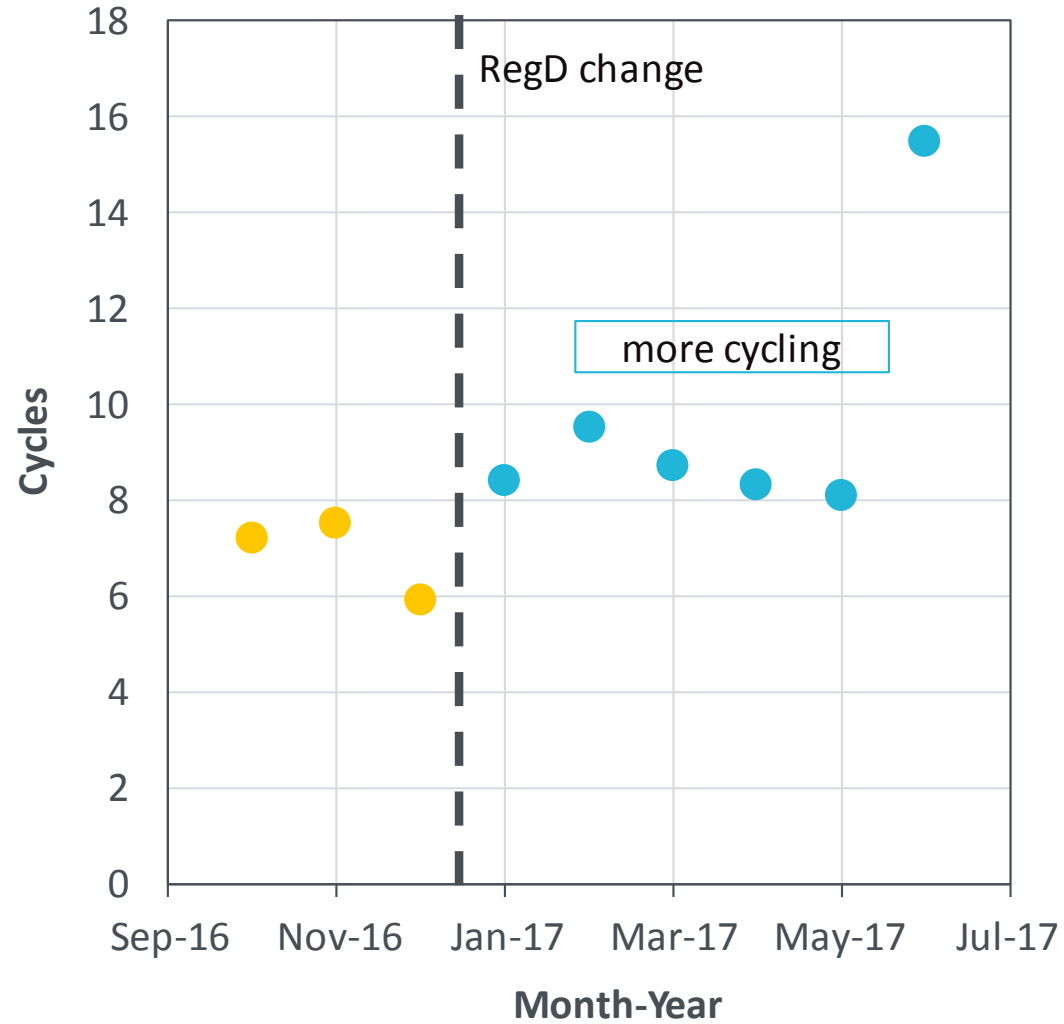
- **RegD** is the **frequency regulation signal** for fast-response resources (**batteries**) in PJM's frequency regulation market, designed in 2012
- PJM found that fast-response resources would sometimes worsen the regulation problem, requiring more slow-response **RegA** resources (**steam turbines**) to fix the problem
- PJM reengineered the RegD signal in Jan. 2017, causing batteries to operate longer and exchange more energy with the grid
- Batteries are working more and aging faster
- What is the impact on life?



PERFORMANCE CHANGE (NOV. 01, 2016 – FEB. 28, 2017)



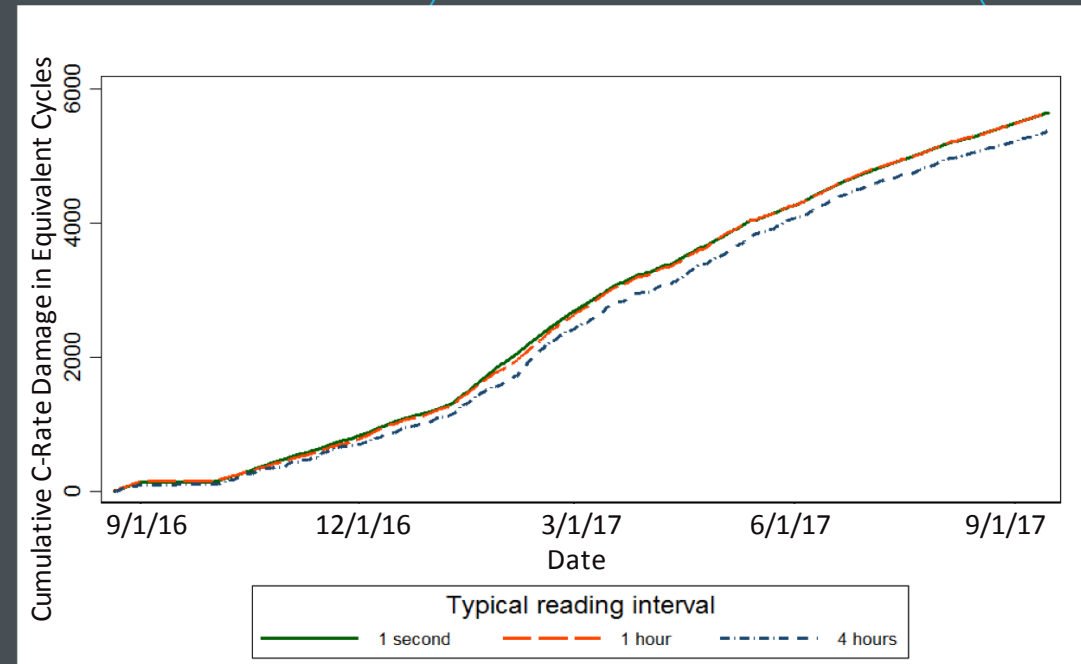
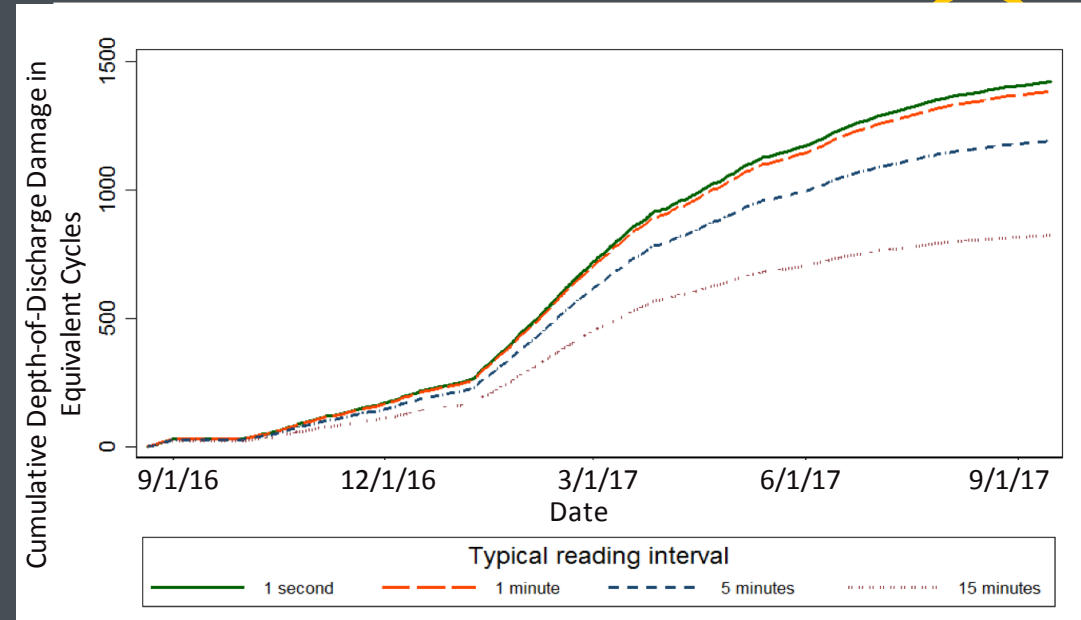
PERFORMANCE CHANGE

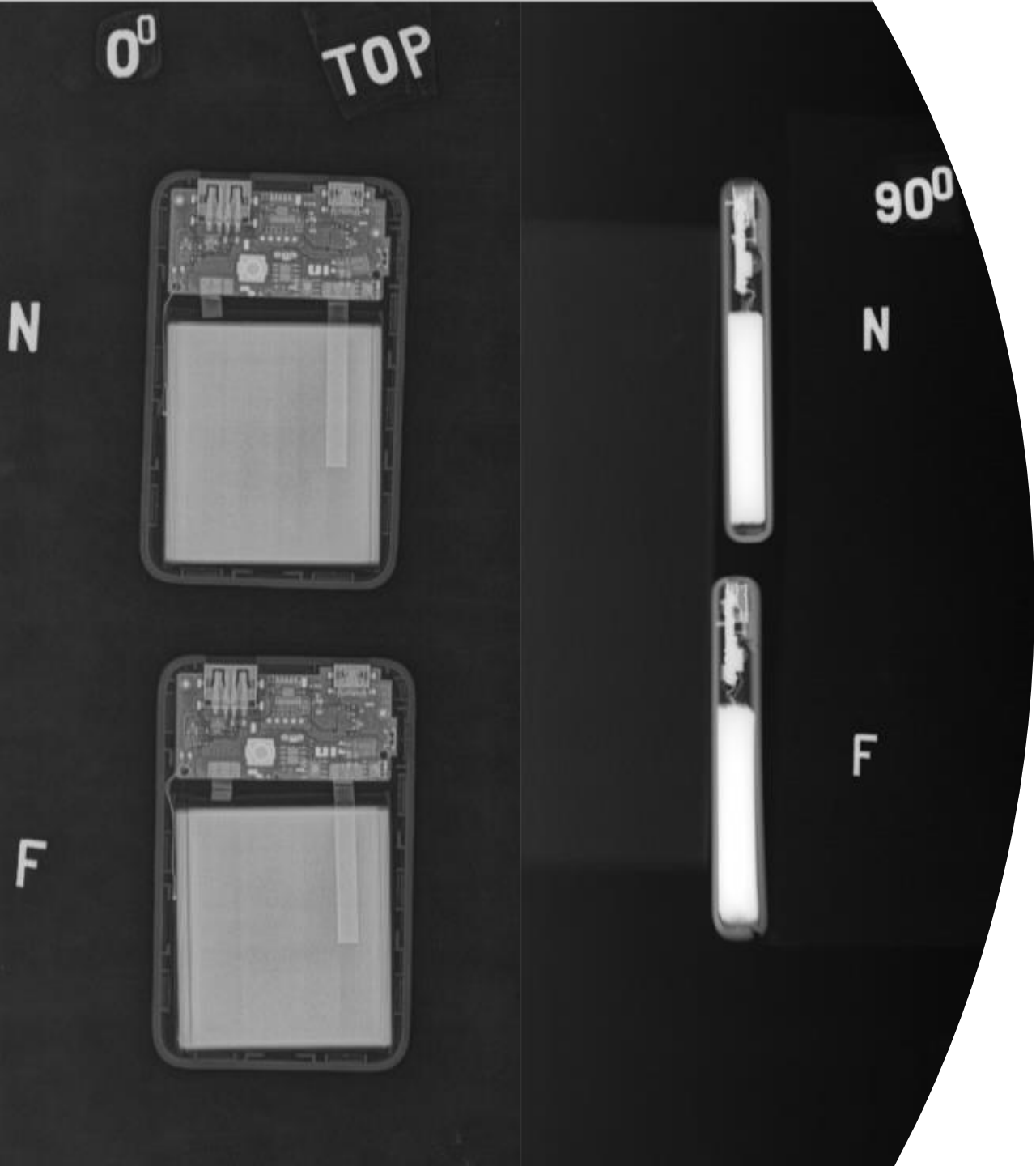


CYCLING DAMAGE AND OPERATIONAL LIFE

Intertek AIM is developing a model to quantify battery cycling damage.

- Based on methodology used for modelling plant cycling damage
- Uses rain flow counter to quantify damage in equivalent cycles
- Accounts for damage due to:
 - Depth of charge/discharge
 - Rate of charge/discharge
 - Estimate a possible 20%-30% decrease in life.



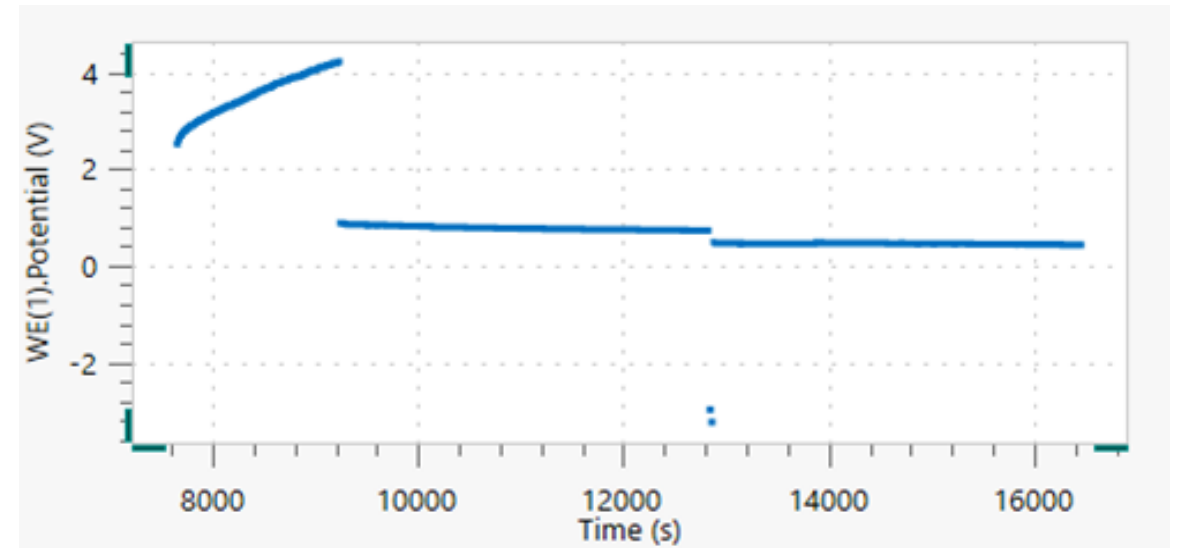


TESTING AND INSPECTIONS

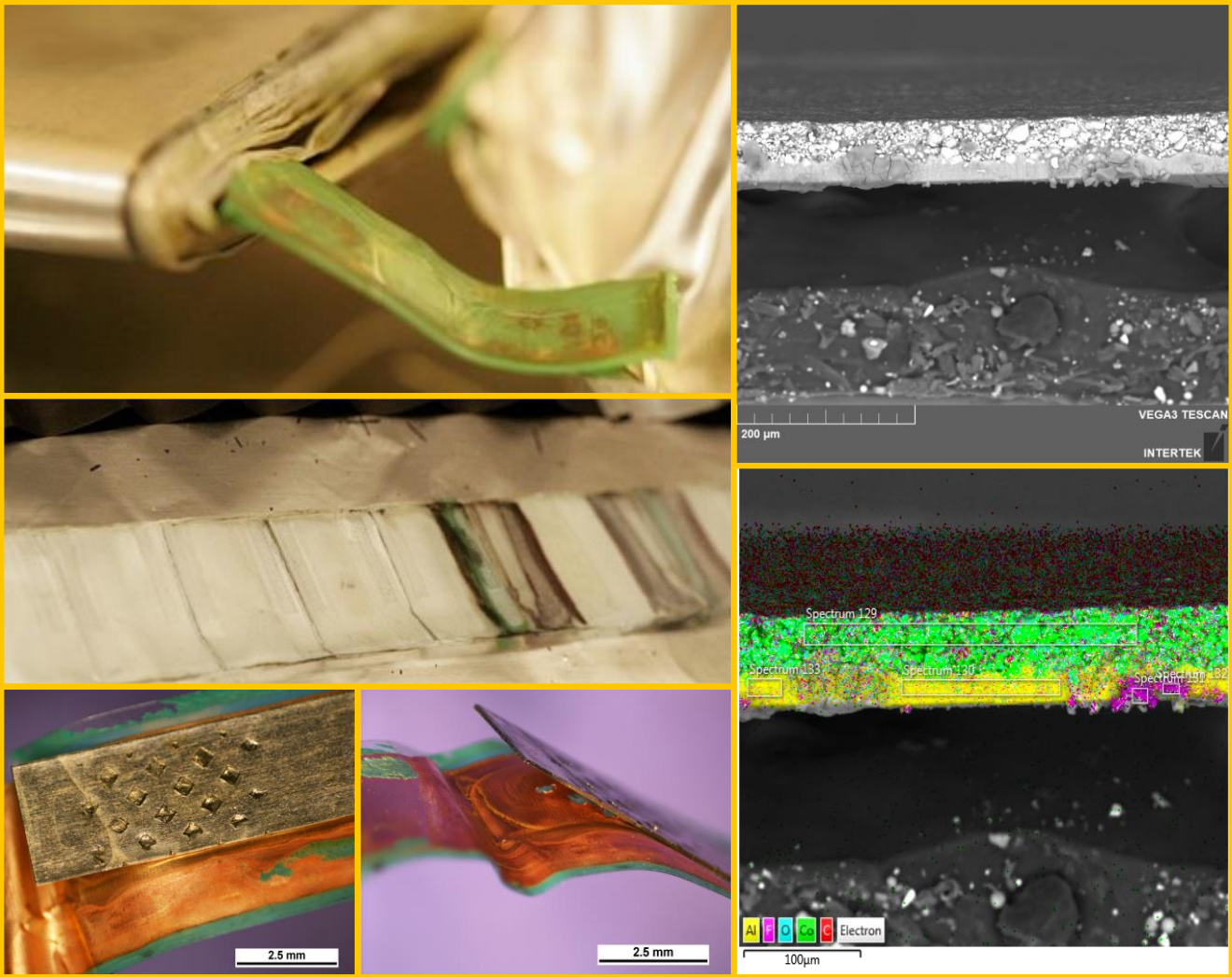


Regular testing and inspections are necessary to adequately track damage and remaining life.

Intertek AIM is developing condition assessment techniques targeted at large scale battery storage systems, which leverage our electrochemistry expertise and experience in non-destructive testing and inspections.



QUALITY ASSESSMENTS & FAILURE ANALYSIS



QUESTIONS?

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SIGNAL CHANGE



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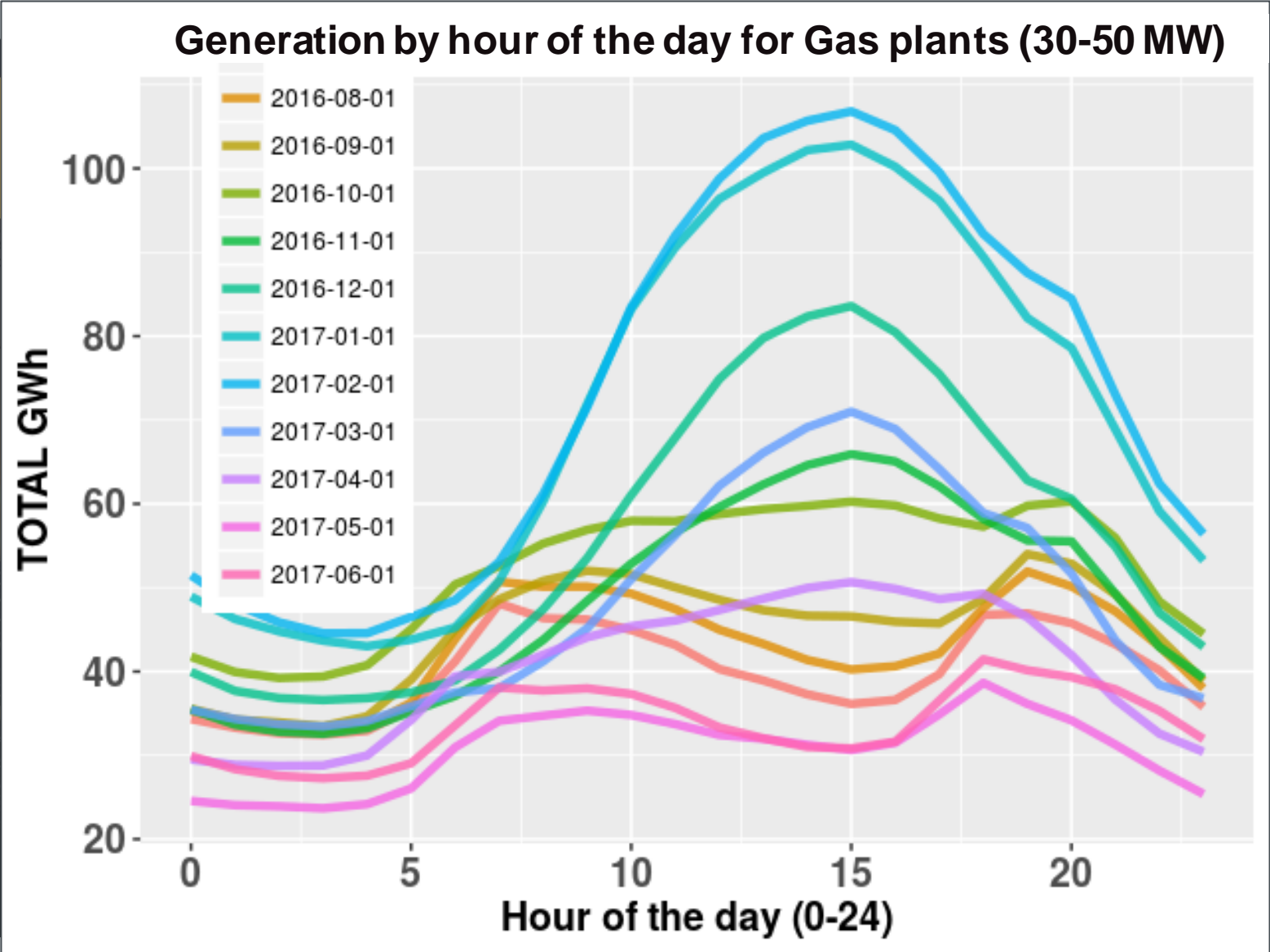
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Plant Quick Search

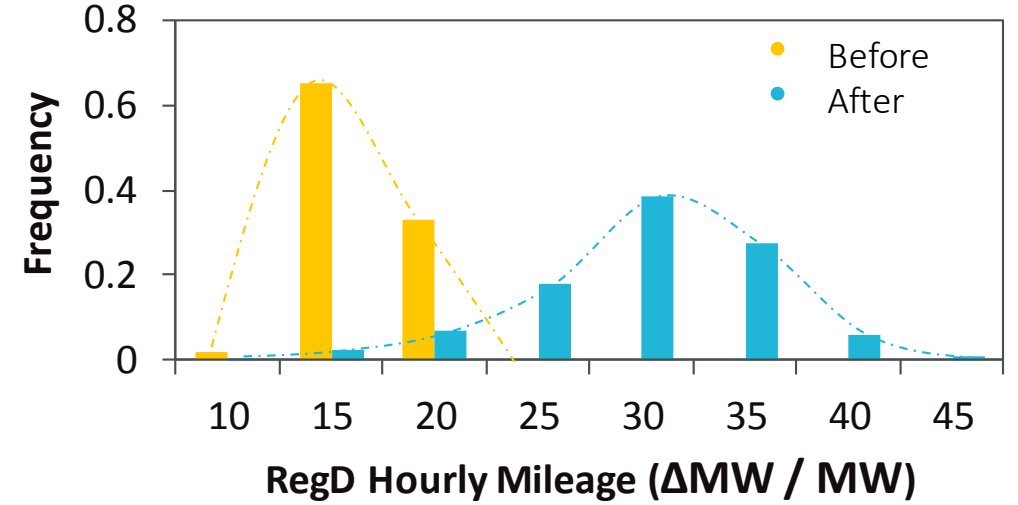
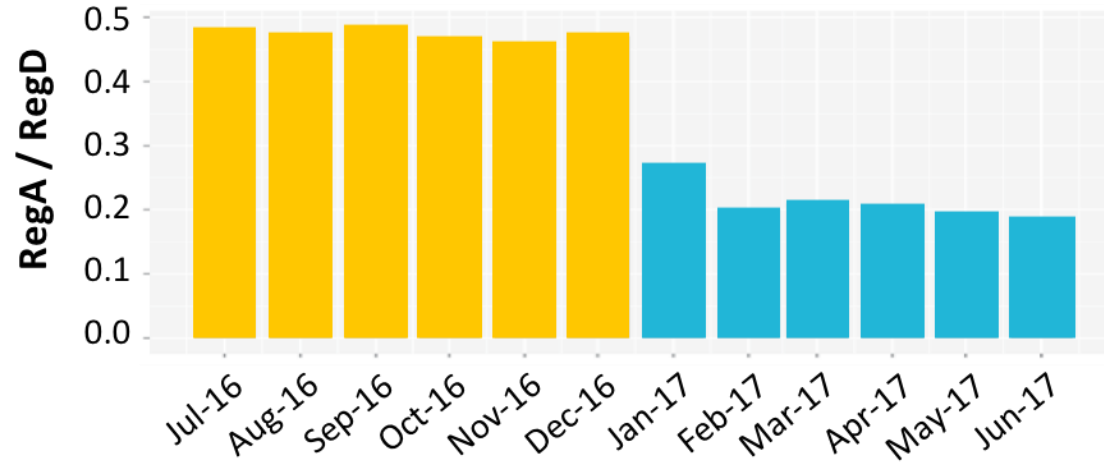
SIGNAL CHANGE



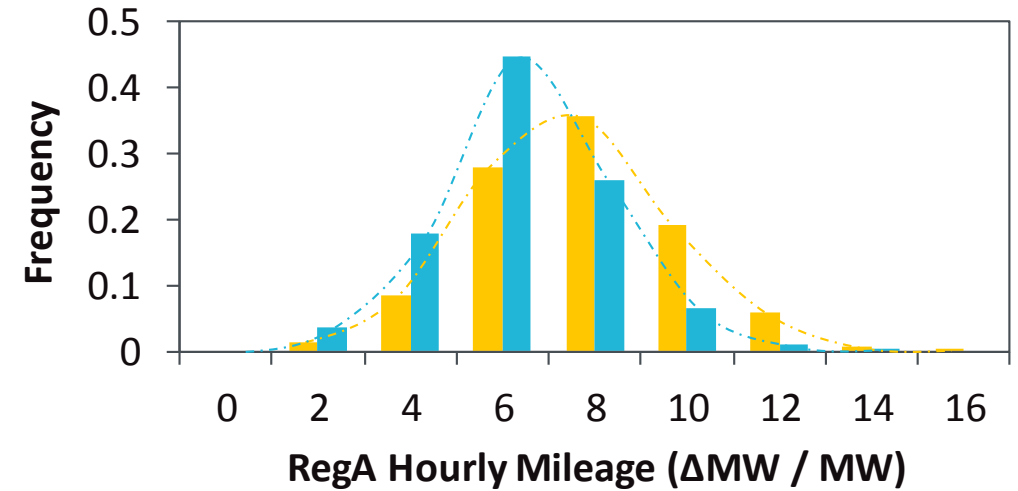
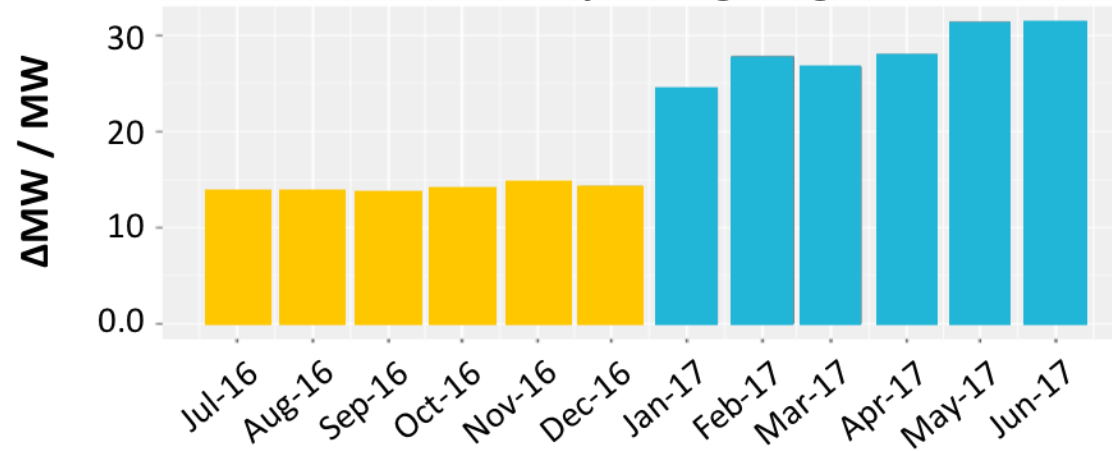
RegD SIGNAL CHANGE



Monthly Average Mileage Ratio



Monthly Average RegD



SIGNAL CHANGE

