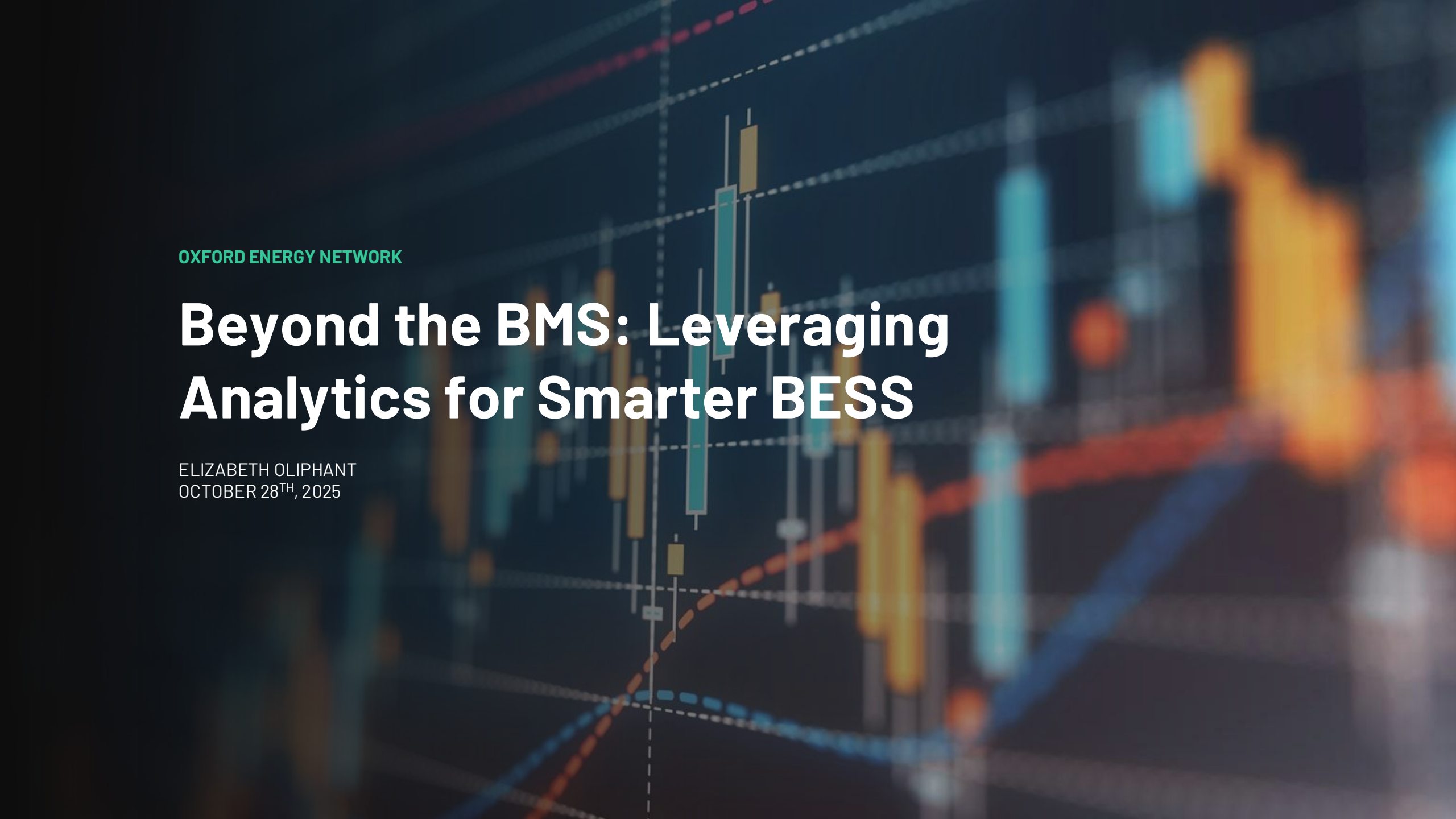


OXFORD ENERGY NETWORK

Beyond the BMS: Leveraging Analytics for Smarter BESS

ELIZABETH OLIPHANT
OCTOBER 28TH, 2025

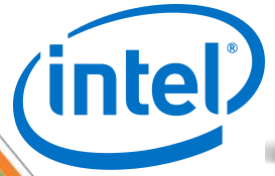
ACCURE

Agenda

- Introduction
- The BMS
- State of Charge (SOC)
- Predictive analytics

INTRODUCTION

A California kid, Liz Oliphant grew up in the Silicon Valley with the Pacific to the West & Tahoe to the East – a blend of tech & nature!



UNIVERSITY OF MICHIGAN

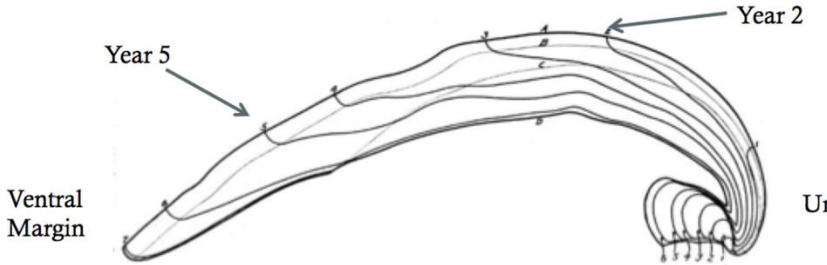
INTRODUCTION

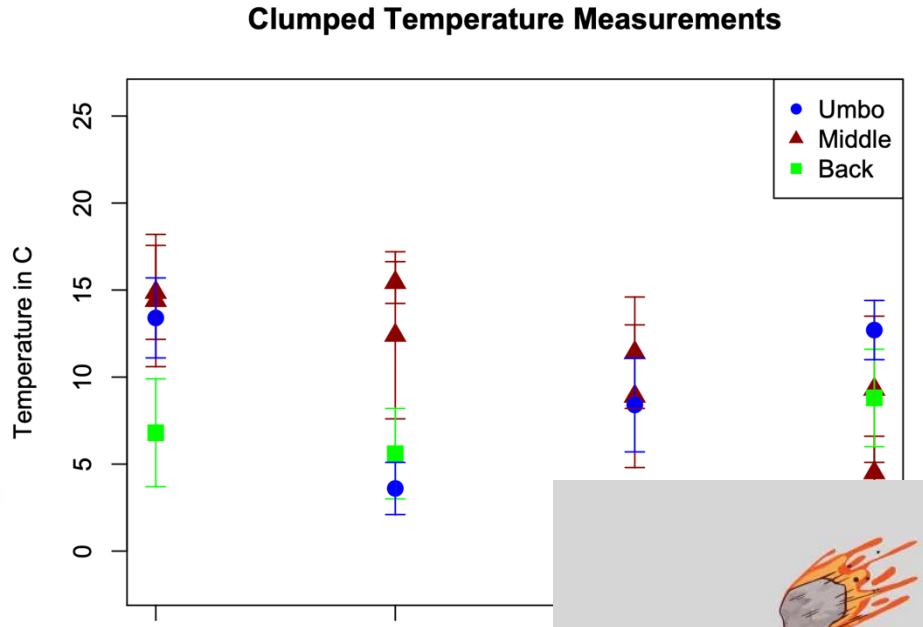
In university, Liz's research was on paleoclimate – Understanding the chemistry behind climate change sparked a commitment

UNIVERSITY OF MICHIGAN

Climate change research

- Researched under Professor Dr. Sierra Petersen
- **Project focus:** Reconstructing paleoclimate around the KT extinction period (dinosaurs!)
- **Material:** Shells used as climate proxy due to growth patterns reflecting environment
- **Methodology:** Isotopic composition of oxygen & carbon measured using mass spectrometry



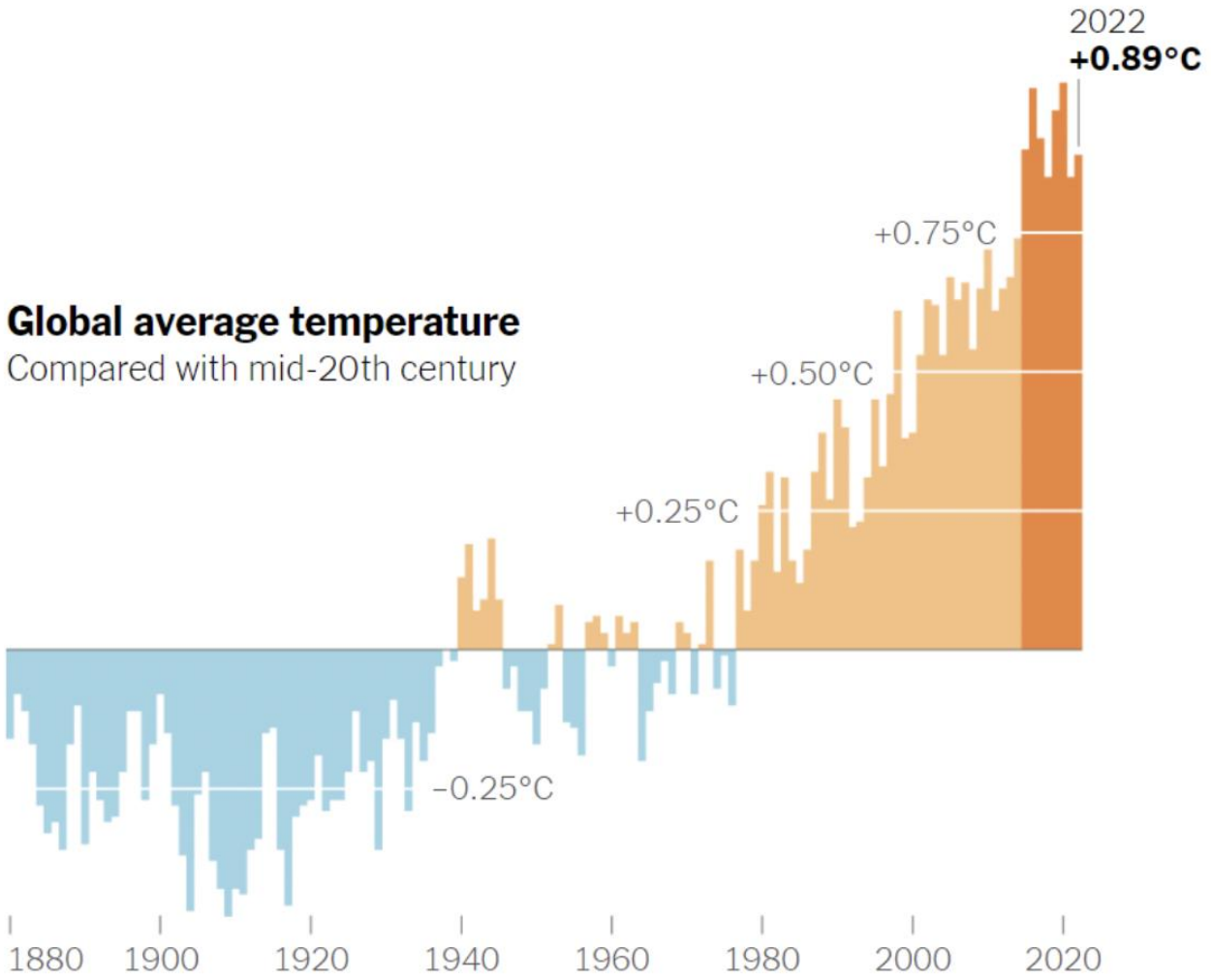


Clumped isotope data revealed significant environmental and biological shifts

A keen interest in climate change and chemical relationships was born

INTRODUCTION

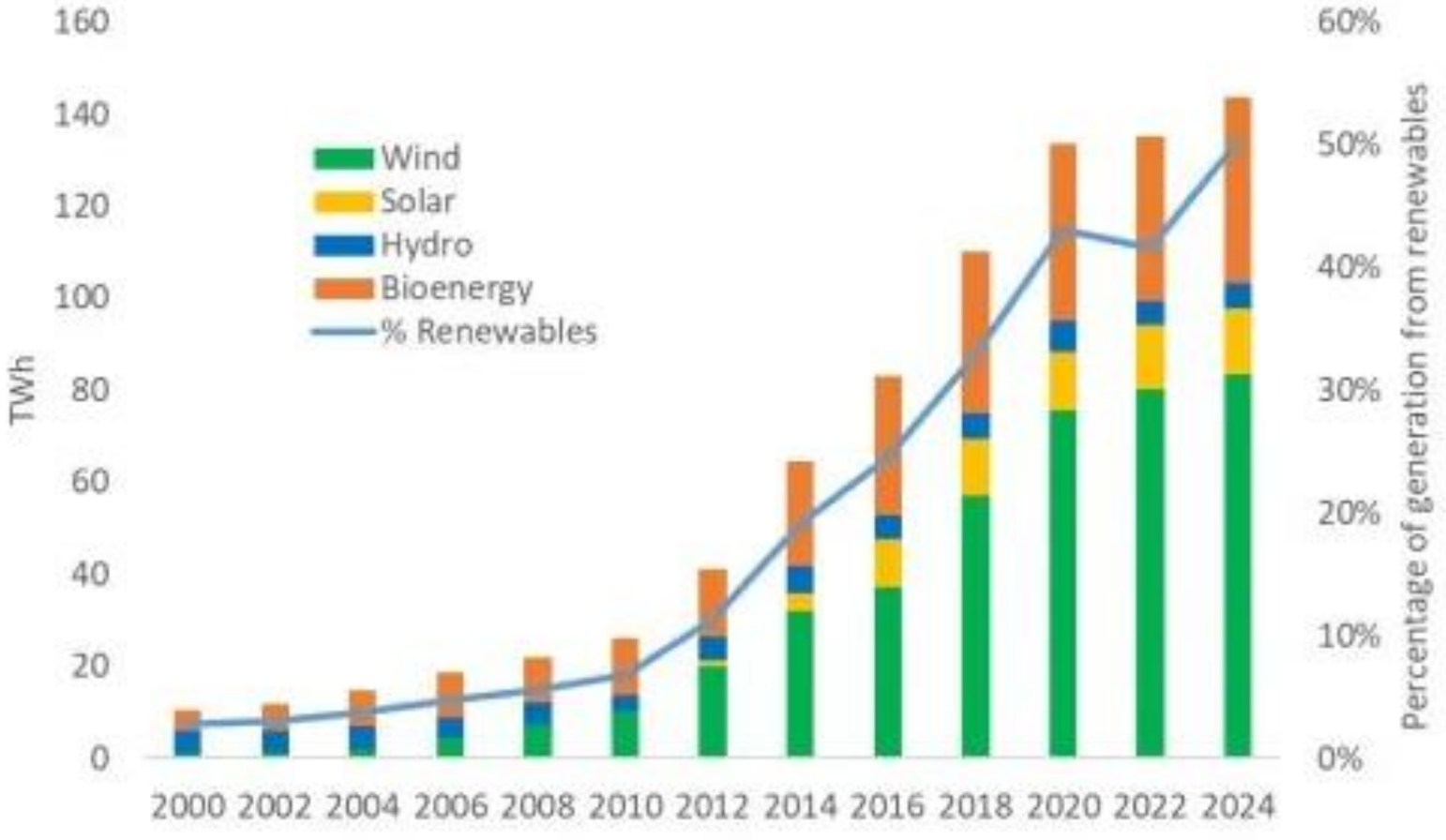
Shifting to the modern day, there is another clear climate challenge



NASA Goddard Institute

INTRODUCTION

The UK's renewable capacity has hockey sticked since 2010 – reaching >50% of 2024 generated electricity



DESNZ & Solar Power Portal

INTRODUCTION

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FULBRIGHT

UNIVERSITY OF MICHIGAN

UNIVERSITY OF OXFORD

APRICUM

ACCURE
Battery Intelligence

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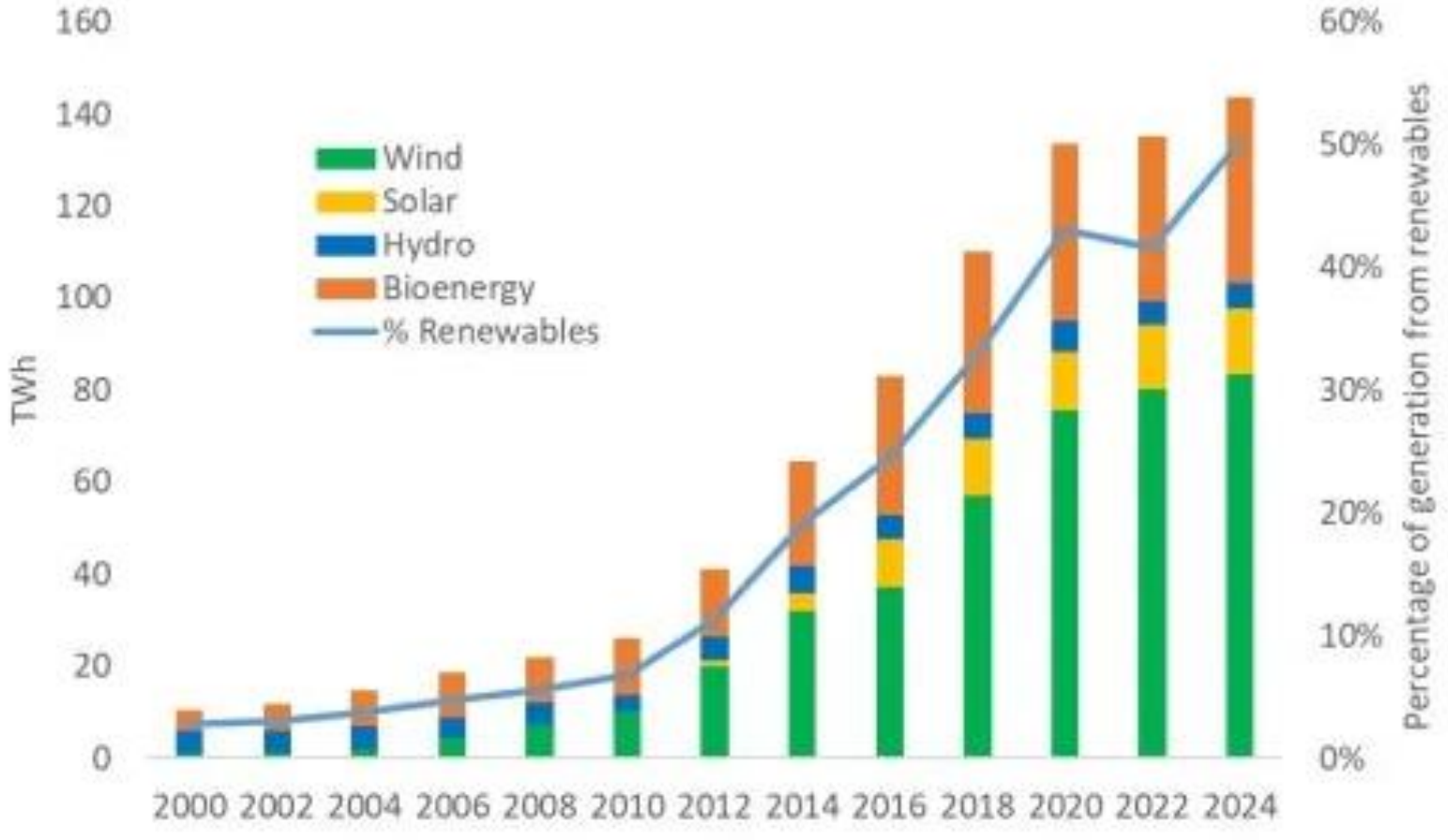
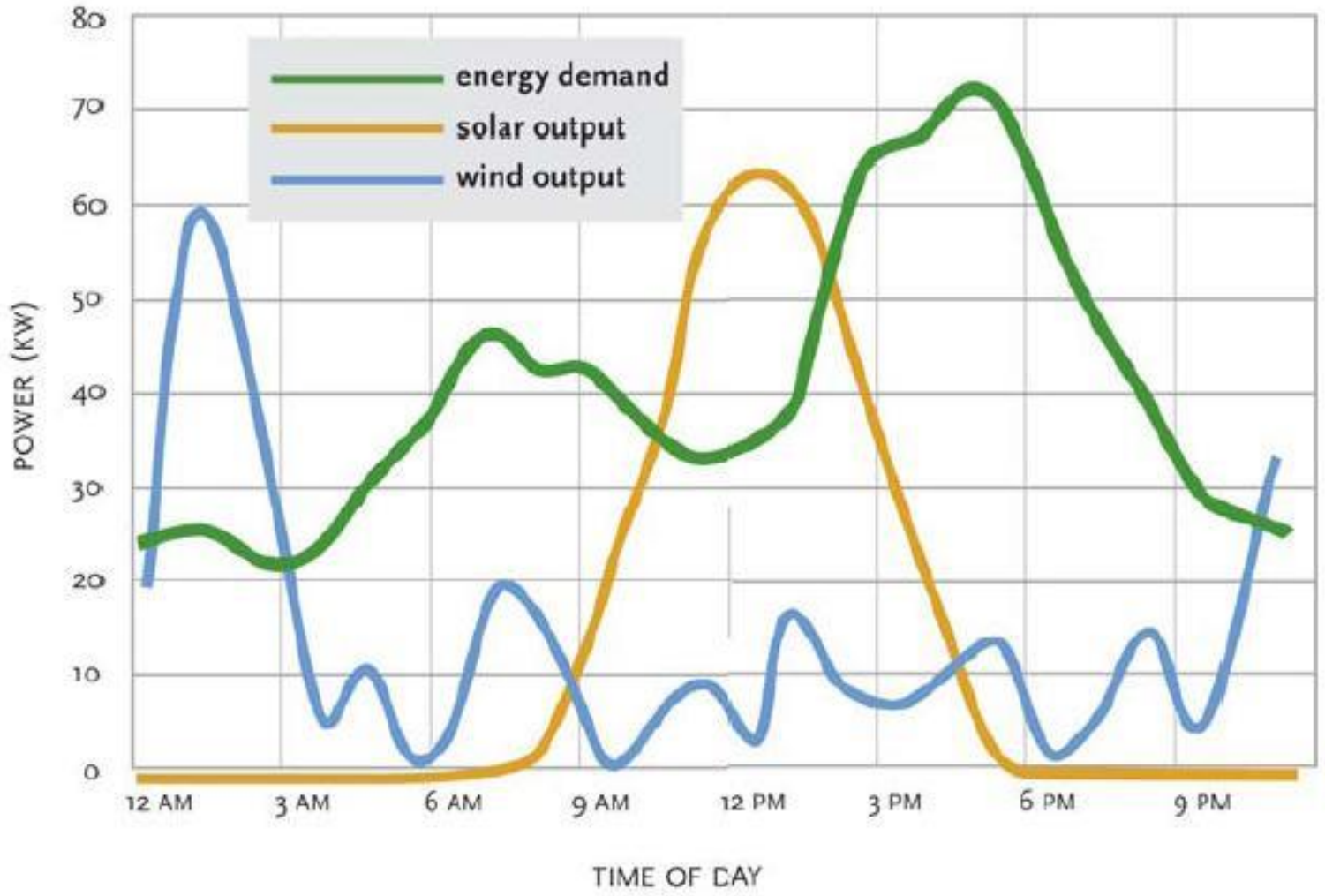


INTRODUCTION

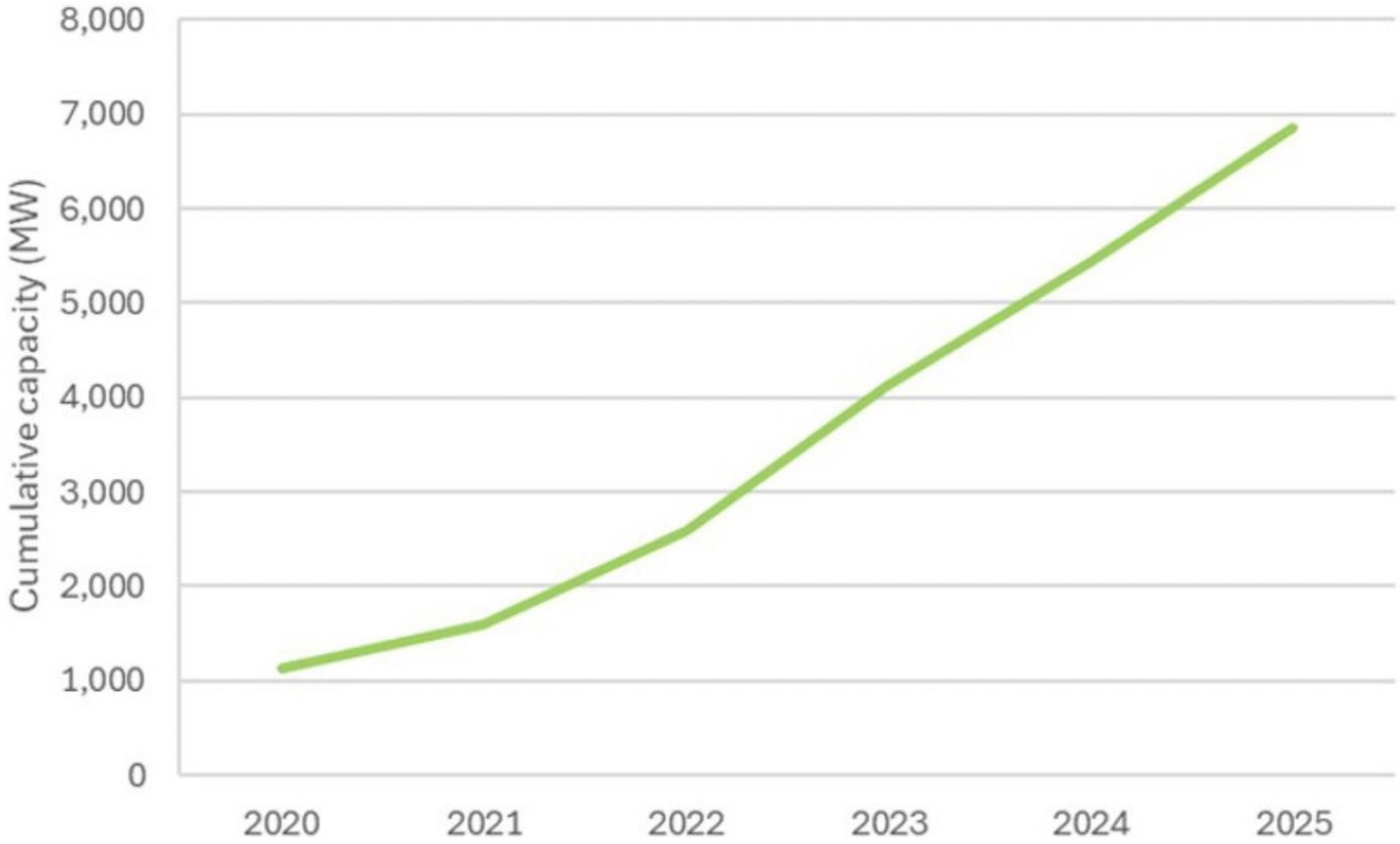
Renewable generation loads do not match the energy demand thus the grid requires load shifting



Edrisian et. al, 2013

INTRODUCTION

BESS cumulative capacity in the UK has grown 7-fold since 2020 reaching ~7GW in 2025



Sutherland, EnergyPulse
RenewableUK 2025

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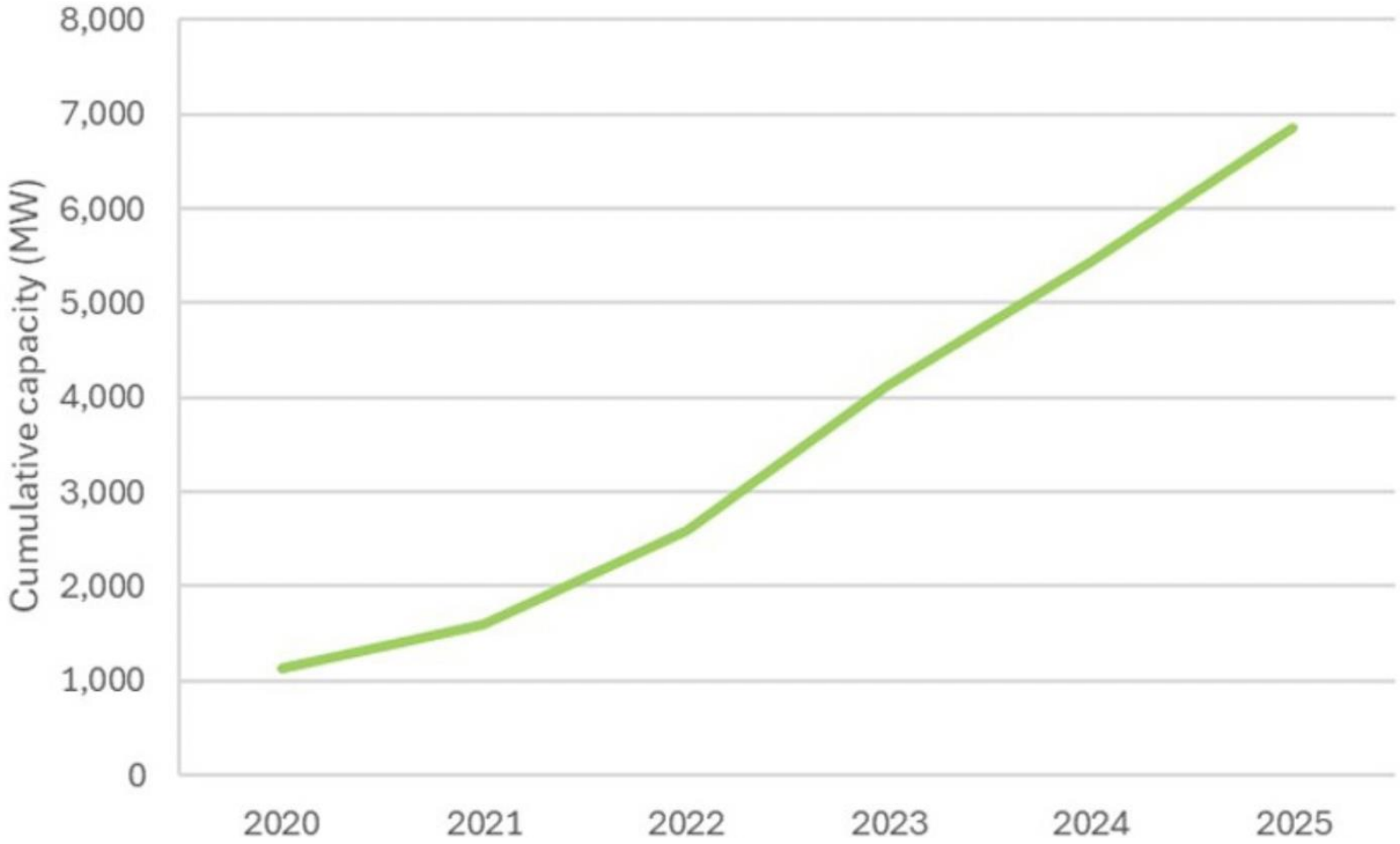
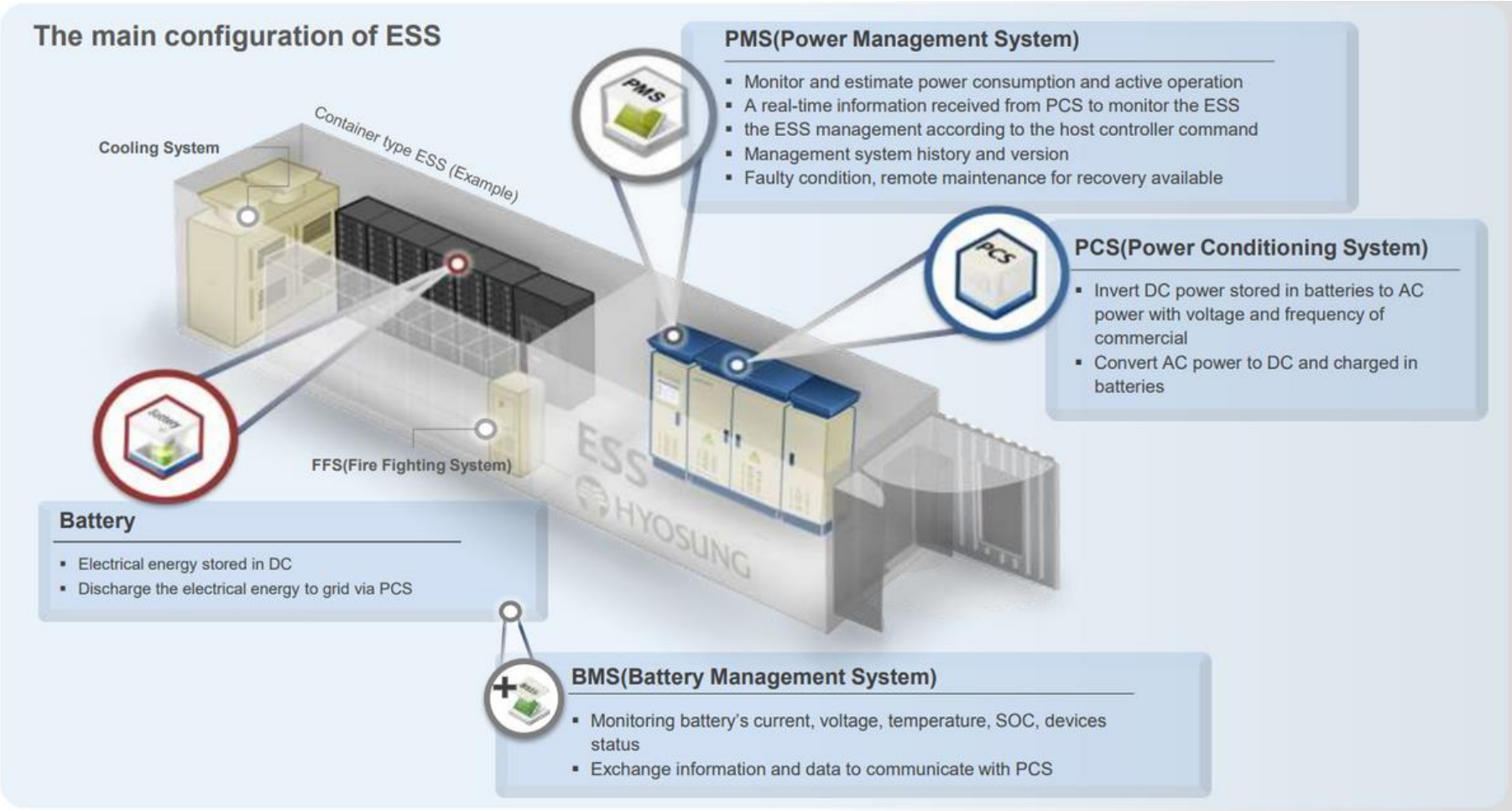


Sutherland, EnergyPulse
RenewableUK 2025

THE BMS

BESS systems are comprised of batteries, PMS, PCS, HVAC & other components with the BMS being the brains of the operations



THE BMS

The BMS's fundamental job is to keep the battery safely operating, with compact and cost-conscious designs

BMS responsibilities

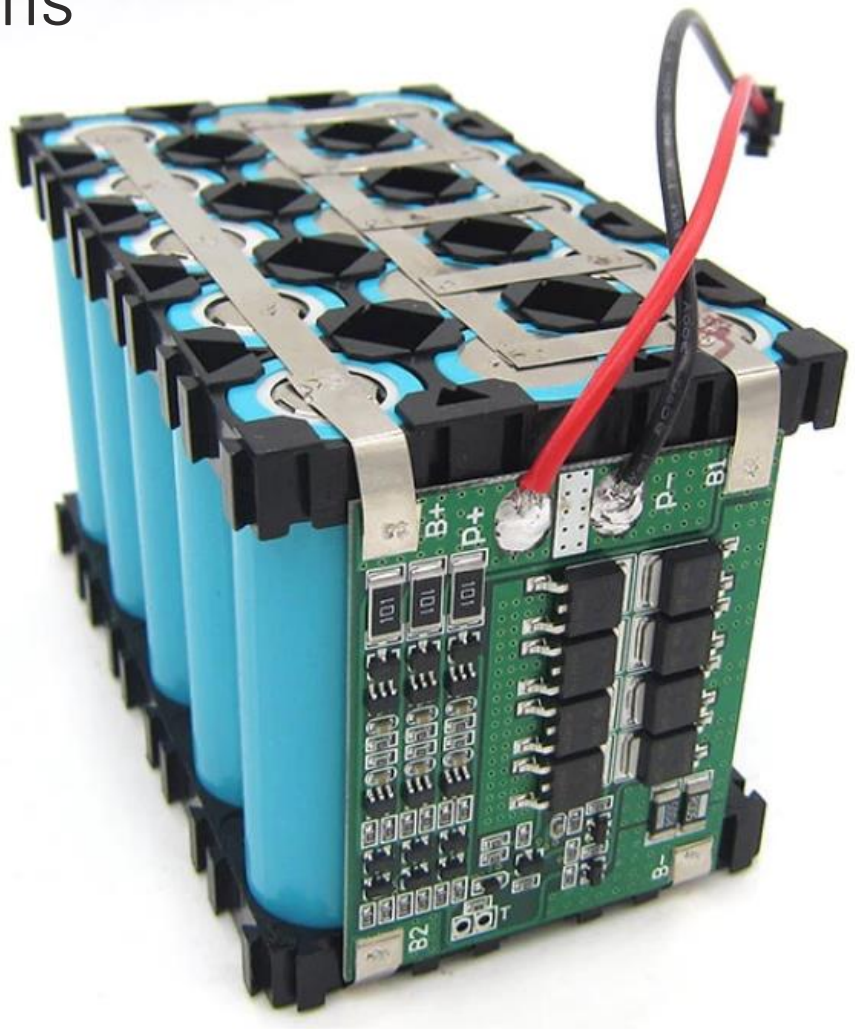
Communicate: Shares data with the EMS/PCS for system control and safety

Monitor: Tracks voltage (V), current (A), temperature (°C), and estimates State of Charge (SOC), and State of Health (SOH)

Protect: Prevents overcharge, overdischarge, and overheating.

Balance: Keeps cell voltages equal for longer life and better performance.

Design concerns: safe and cheap!



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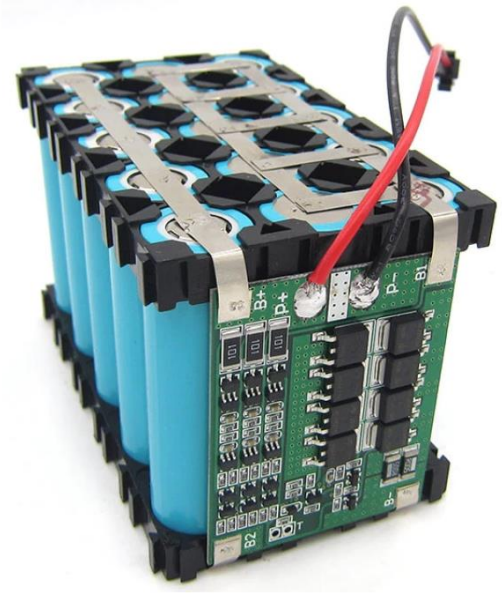
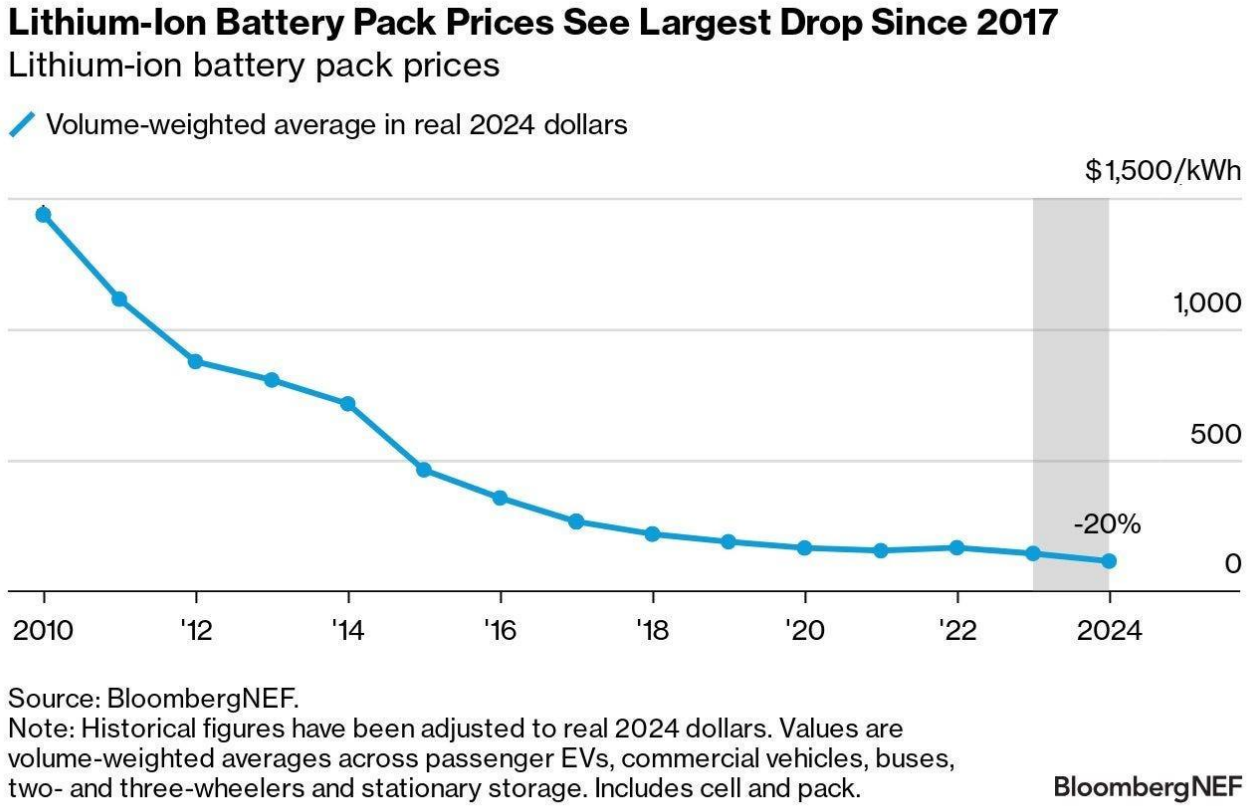
BMS responsibilities
Communicate: with the EMS
Monitor: track V, A, °C, and **estimates** SOC & SOH



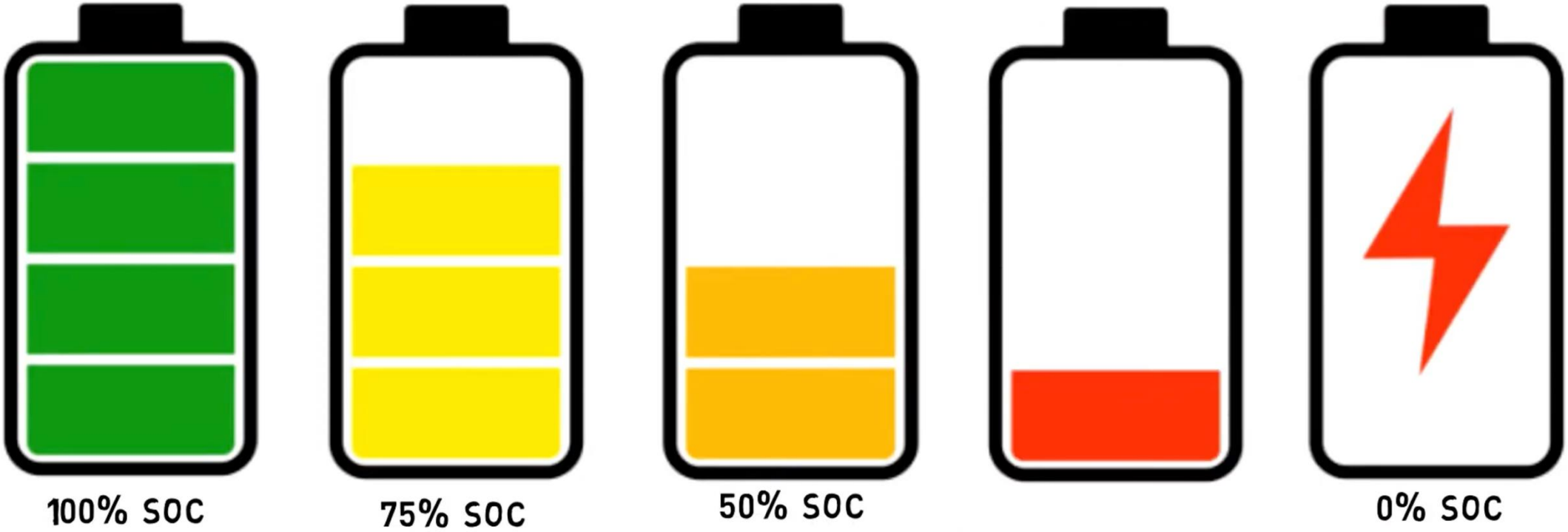
BMSs typically costs between 10-30% of system cost



Duendhd, BloombergNEF

STATE OF CHARGE

Charge within a battery isn't measured, its calculated and harder to determine than you'd think



STATE OF CHARGE

Understanding the state of charge is not just for convenience; it is also essential for safety and long-term battery life

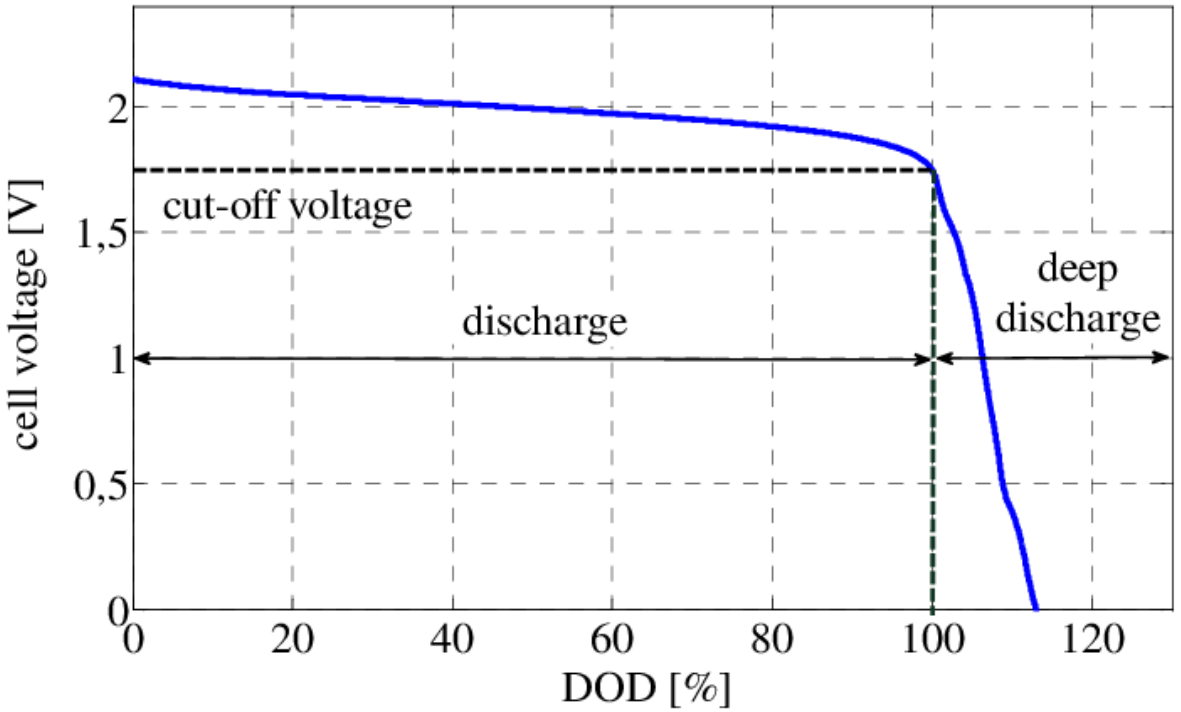
NMC Batteries

- **Normal range:** 3.0–4.2 V
- **Below 2.5 V:** Solid Electrolyte Interphase (SEI) layer breaks down → capacity loss
- **Below 2.0 V:** Copper dissolves, causing shorts circuits & fire risk
- **Below 1.5 V:** Cell is unrecoverable

Prevention: use a BMS cutoff typically ~2.7V

LFP Batteries

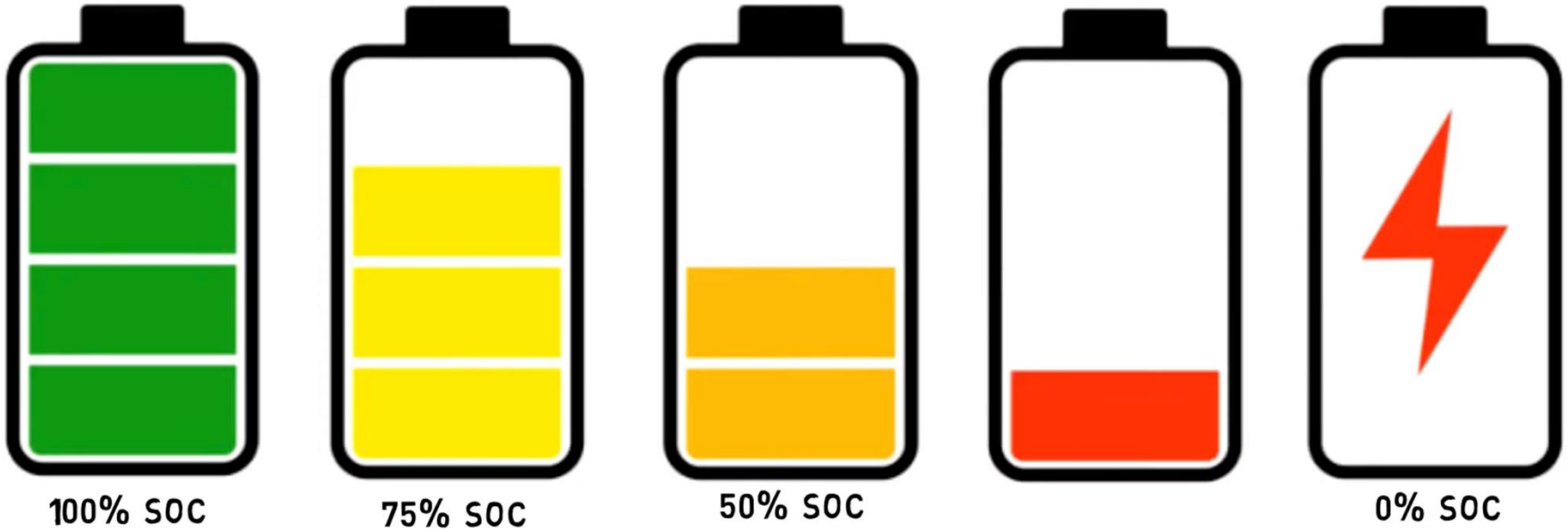
- **Normal range:** 2.5- 3.65
- **Below:** more stable, but undervoltage degrades BESS



Blank et. al, 2012

STATE OF CHARGE

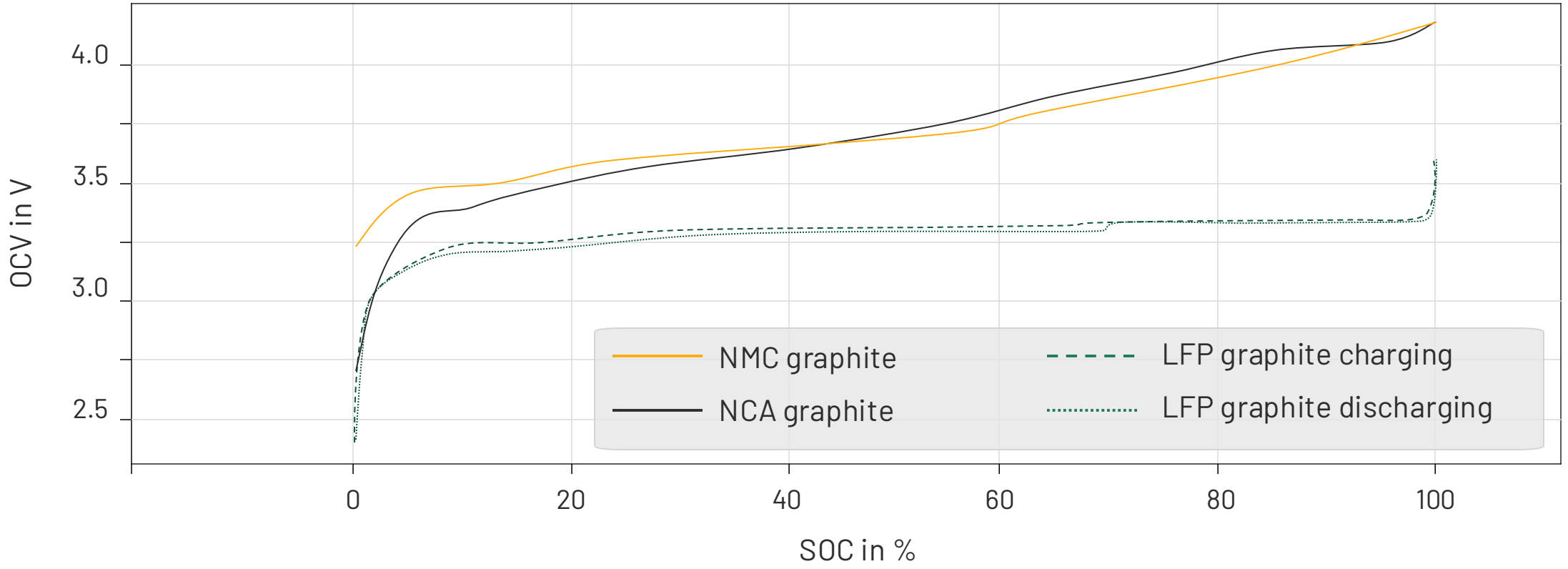
Coulomb counting calculates charge by tracking current flow in and out of a battery over time, but it is prone to error drift



$$SoC(t) = SoC(t-1) + \frac{I(t)}{Q_n}\Delta t$$

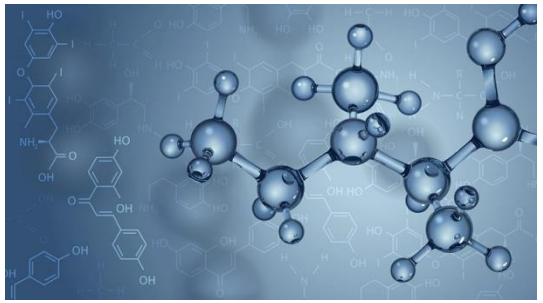
STATE OF CHARGE

The OCV curve is used to calculate charge, but it has precarious relationship with LFP chemistry leading to SOC errors



BESS CHEMISTRY

The chemistry determines the operational properties and best use cases for different batteries

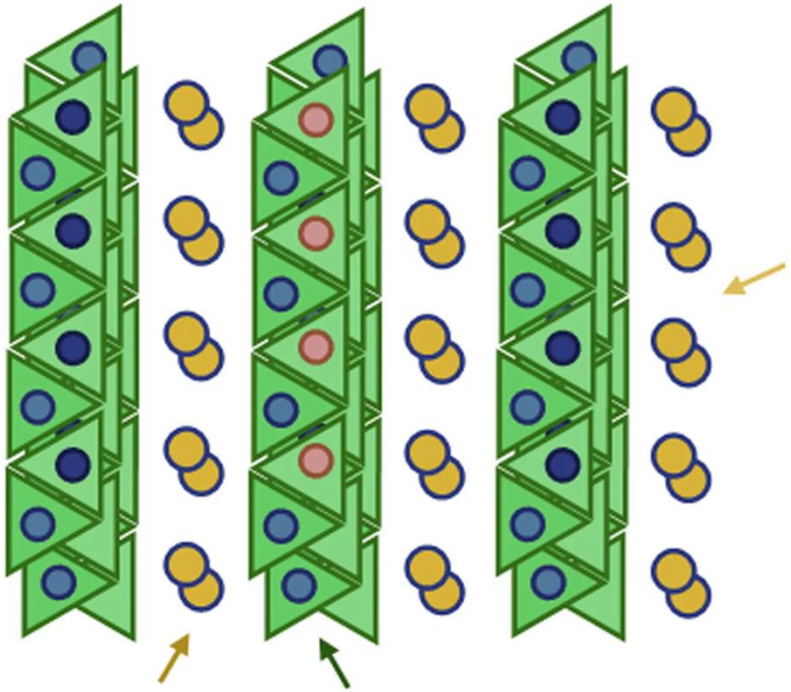
LFP (Lithium Iron Phosphate)	NMC (Nickel Manganese Cobalt)	Other Chemistries
		
• Safe thermal stability • Slightly lower energy density • ~20% cheaper per kWh • 3k-8k cycles	• High energy density • N & C have cost & ethical risks • ~2k cycles	• **NCA (Nickel Cobalt Aluminum):** Exceptional specific energy used in Tesla's premium models (Model S)
LFP forms strong chemical bonds, making it stable, safe, and durable	**NMC provides high voltage but less stability, requiring active cooling and management**	• **Sodium-ion**: Uses abundant, cheap materials, but lower energy density

BESS CHEMISTRY

Chemical composition & structure affect power density & stability

NMC Cathode (layered structure)

Stable to 200-250°C, faster degradation



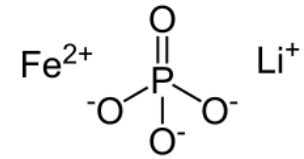
Quick-moving ion highways

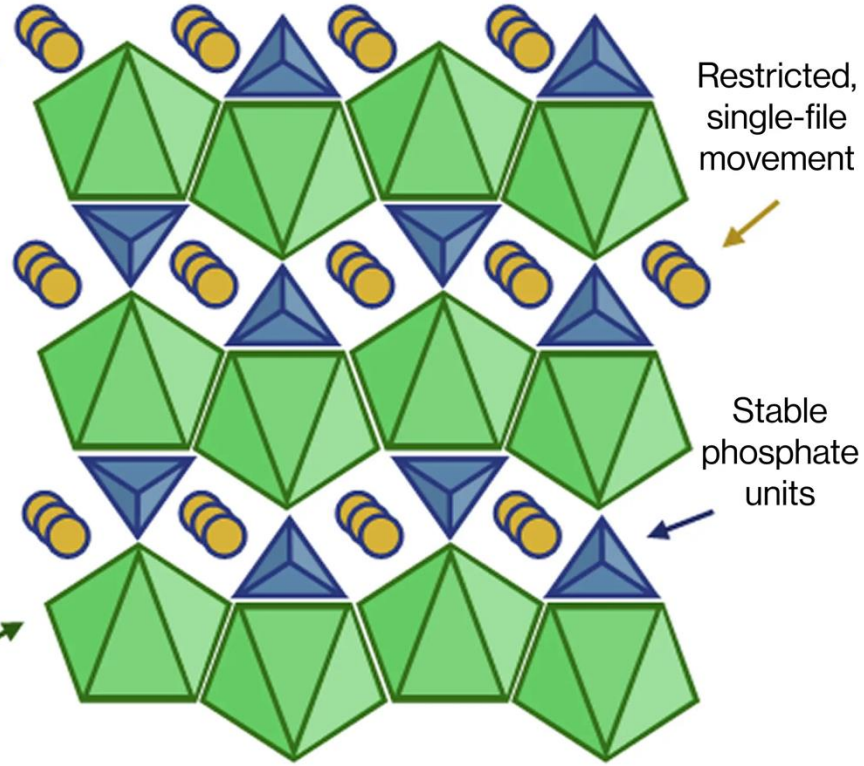
Nickel, cobalt, and manganese form a tetrahedral arrangement

Energy is released during discharging as lithium moves into a more stable state within the cathode, where metal oxides gain electrons.

LFP Cathode (Olivine structure)

Stable to 400-500°C, slower degradation, resiliency





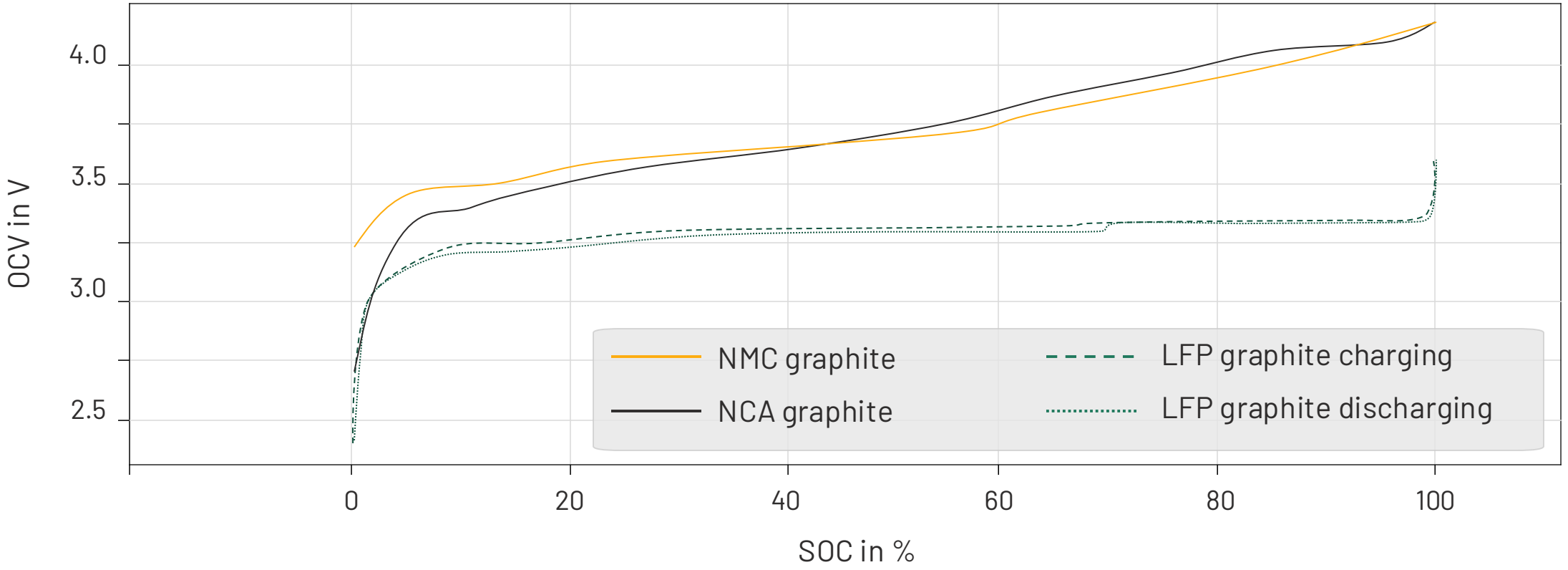
Restricted, single-file movement

Stable phosphate units

Stable iron-oxygen clusters

STATE OF CHARGE

The SOC is complicated to calculate due to precarious relationship between the chemistry & the Open Circuit Voltage (OCV) vs SOC.



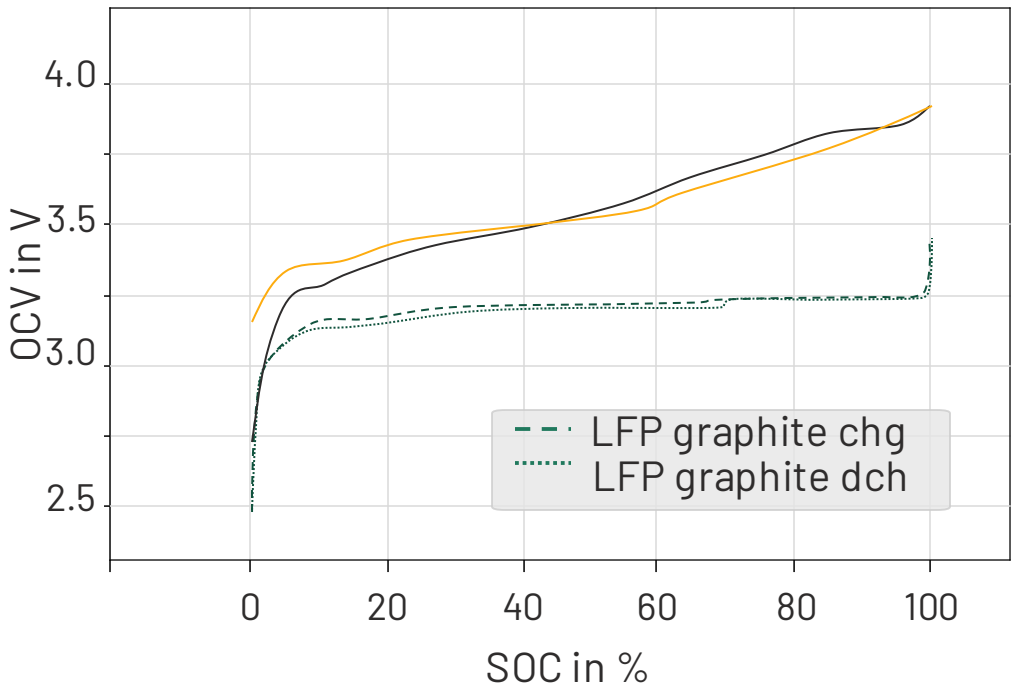
STATE OF CHARGE

LFP has such a flat OCV relationship because 2 phases coexistent

$$LiFePO_4 \rightleftharpoons FePO_4 + Li^+ + e^-$$

Two distinct crystalline phases coexist:
$LiFePO_4$ → when lithium is present
$FePO_4$ (triphylite) → when lithium is removed

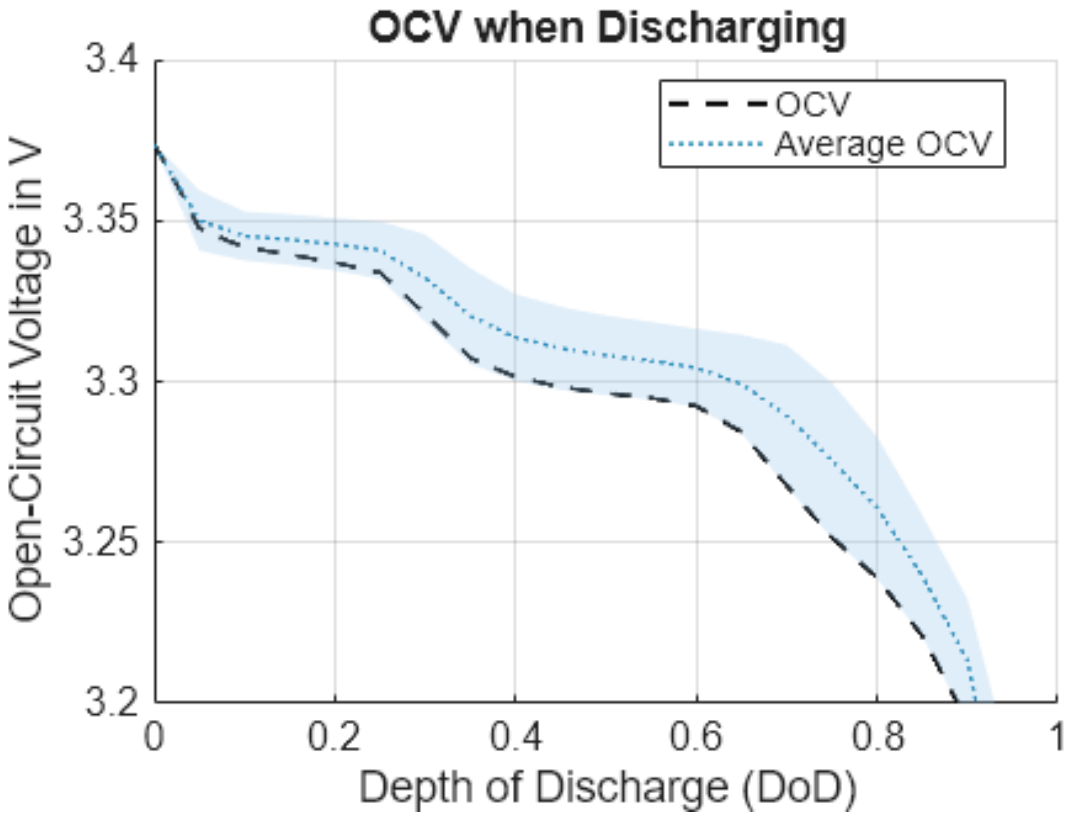
Because the reaction occurs as a **first-order phase transformation** (not gradual), the **chemical potential of Li^+** (thus V) remains nearly constant while both phases coexist.

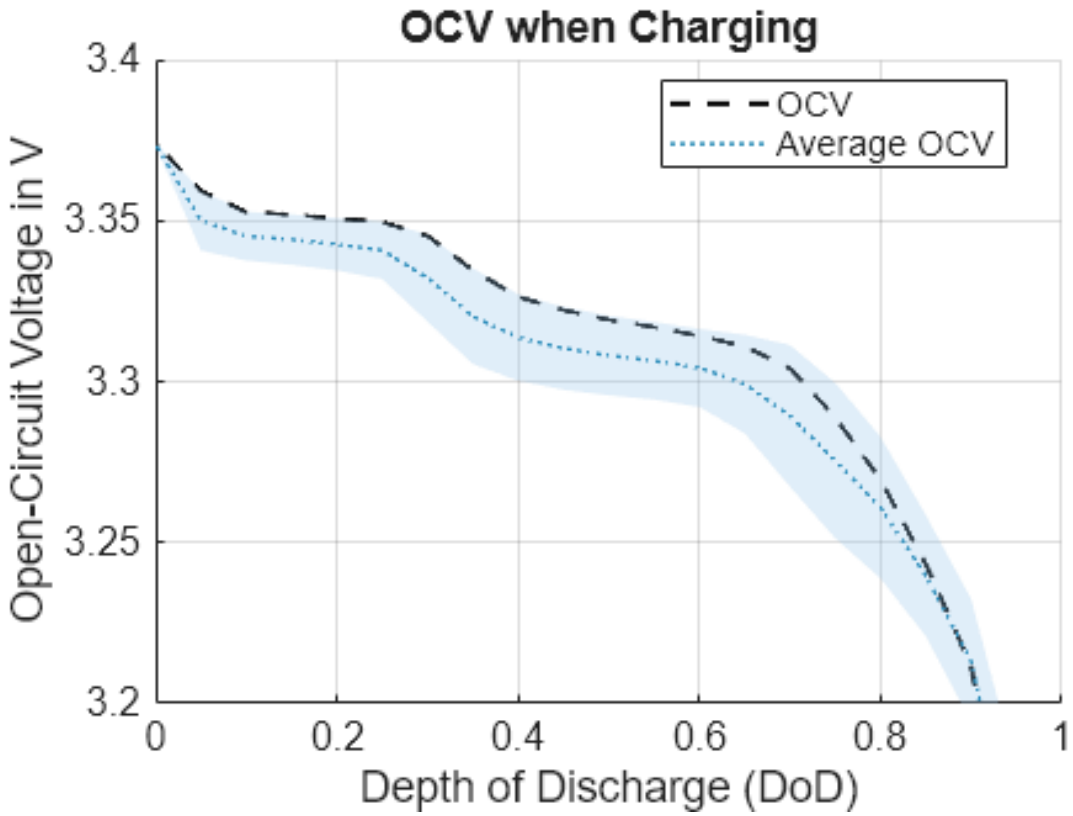


The Two-Phase Reaction Mechanism results in a flat voltage plateau

STATE OF CHARGE

To make matters more complicated, the OCV curve varies slightly in charging & discharging due to voltage hysteresis





https://www.mathworks.com/help/simscape-battery/ug/model-battery-hysteresis-voltage-example.html

Van der Ven et al. &
Gregory Plett

THE BMS

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BMS responsibilities
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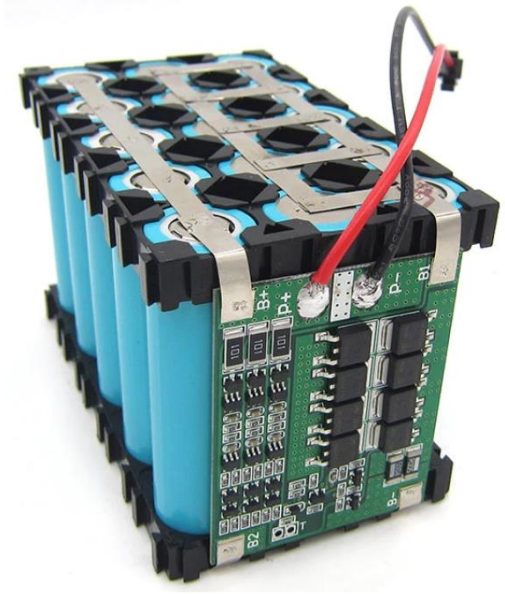
Monitor: track V, A, °C, and estimates SOC & SOH



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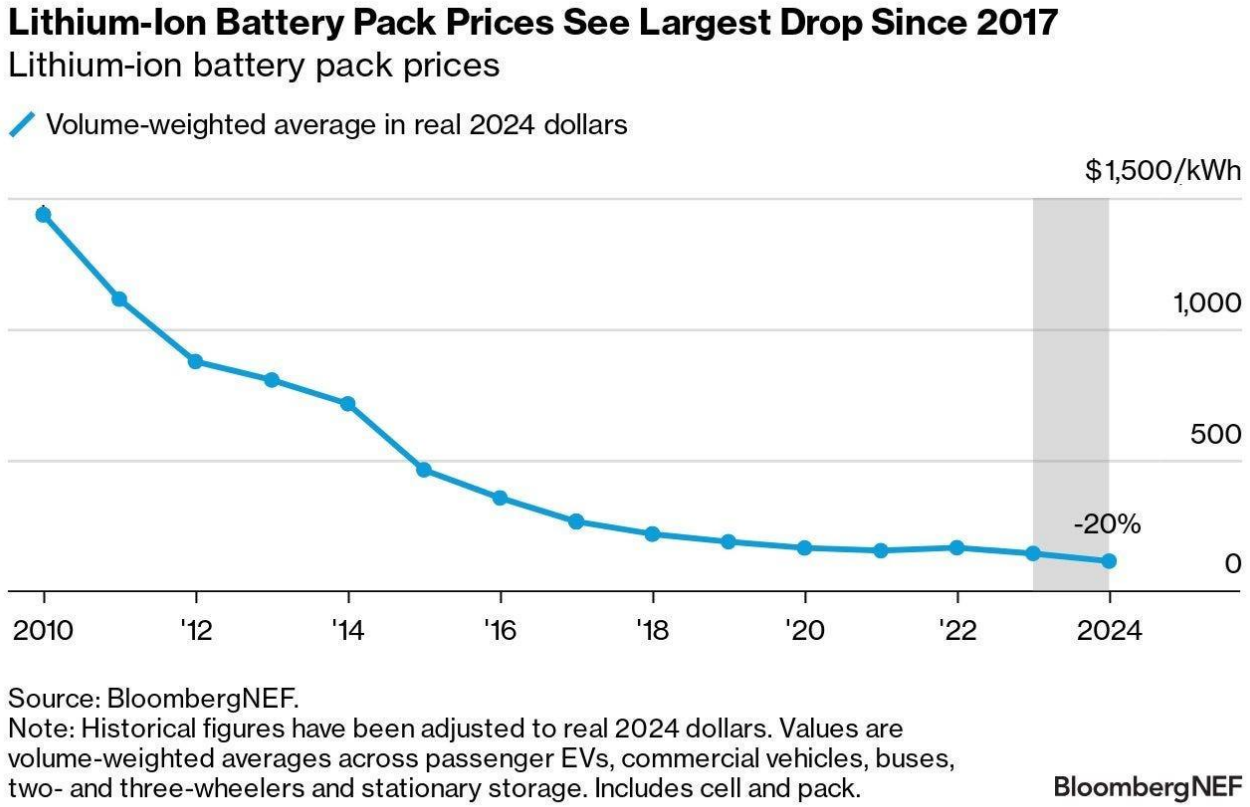
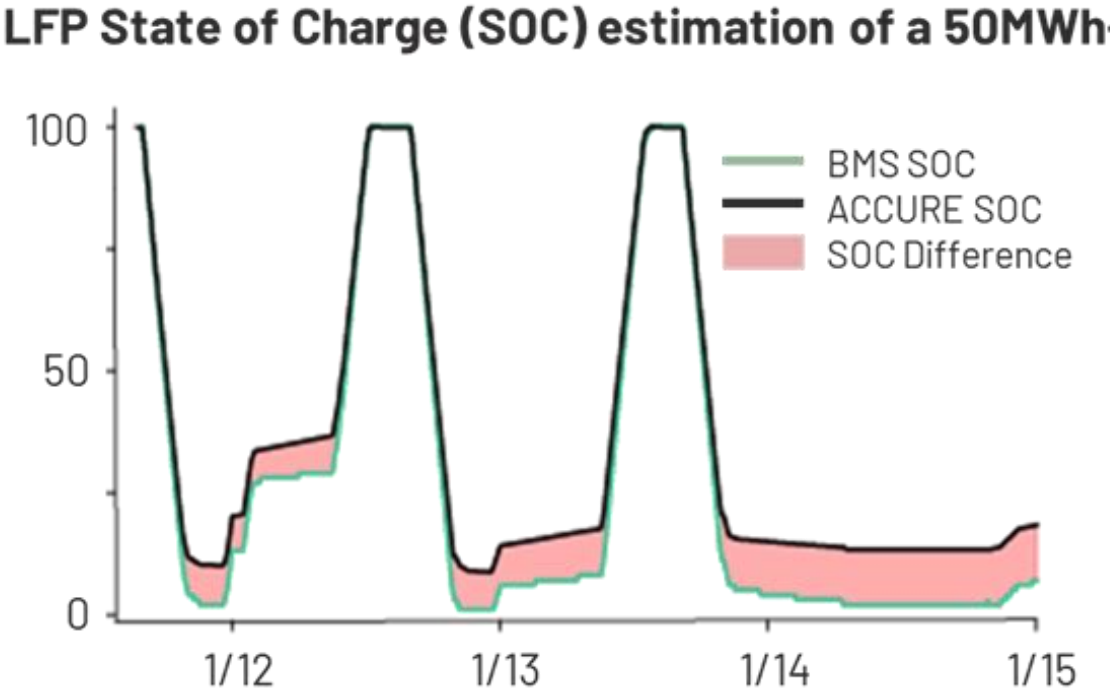


Duendhd, BloombergNEF

STATE OF CHARGE

LFP BMSs often have SOC error margins of >10% – predictive analytics can lower the error margin to +/-2%.

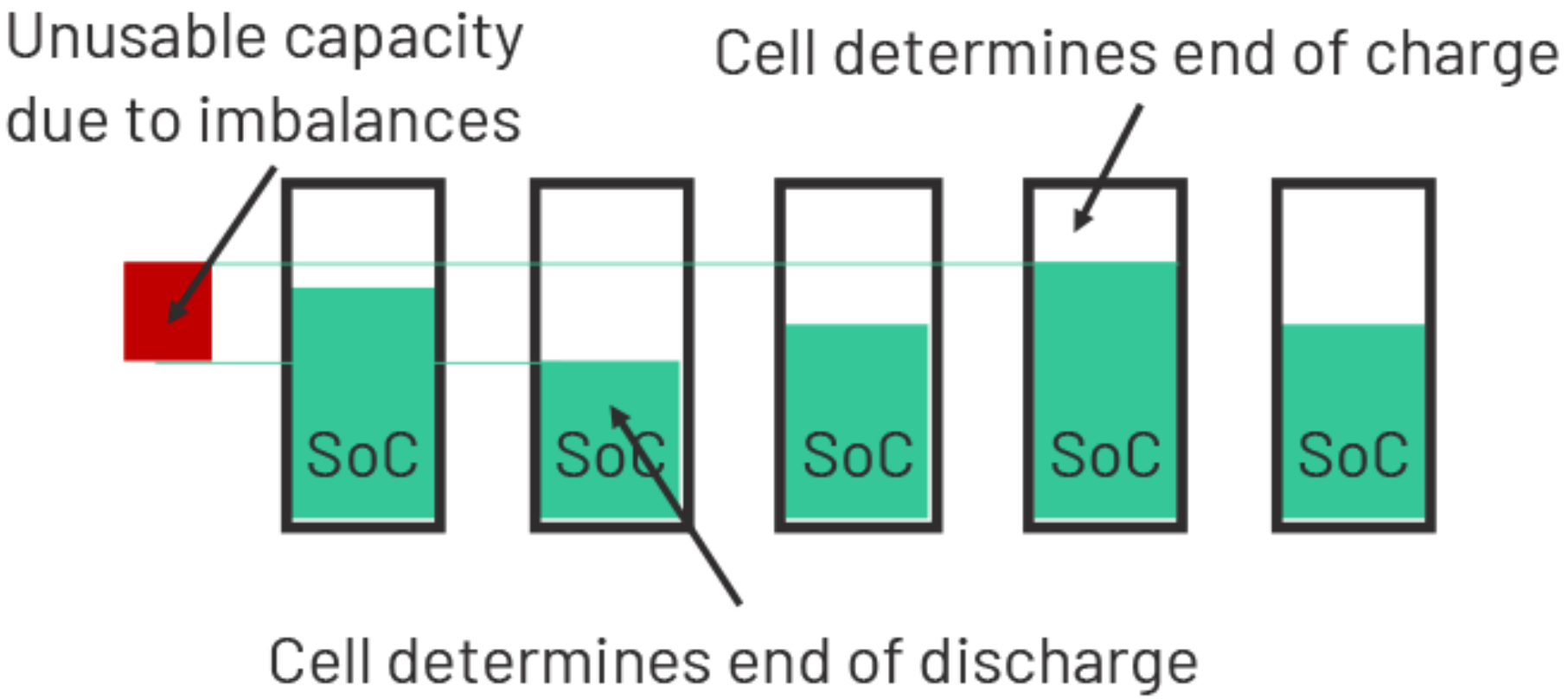


SOC Errors

>12% inaccurate daily

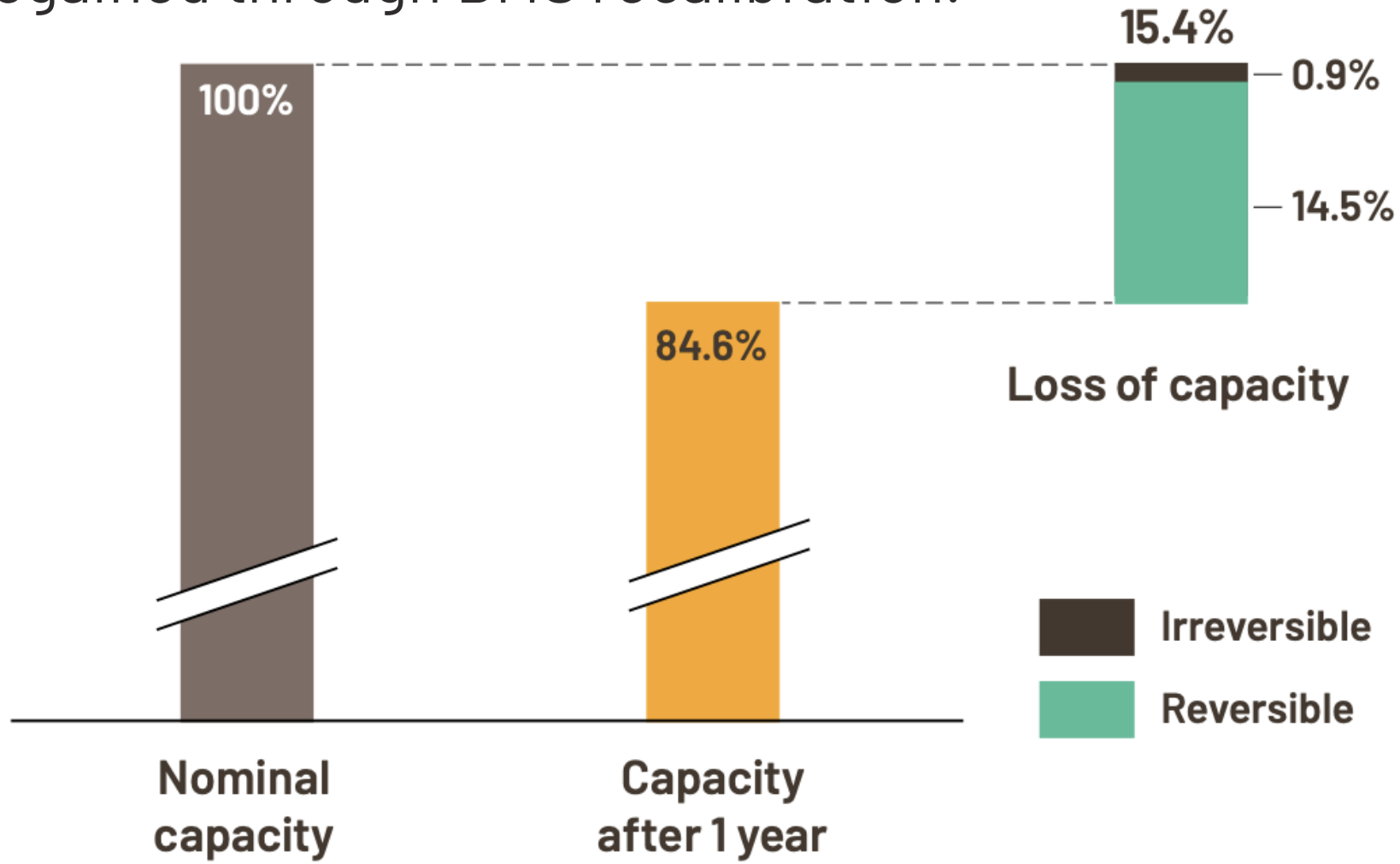
STATE OF CHARGE

SOC estimation errors can amplify system imbalances, leading to portions of the battery's capacity becoming unusable



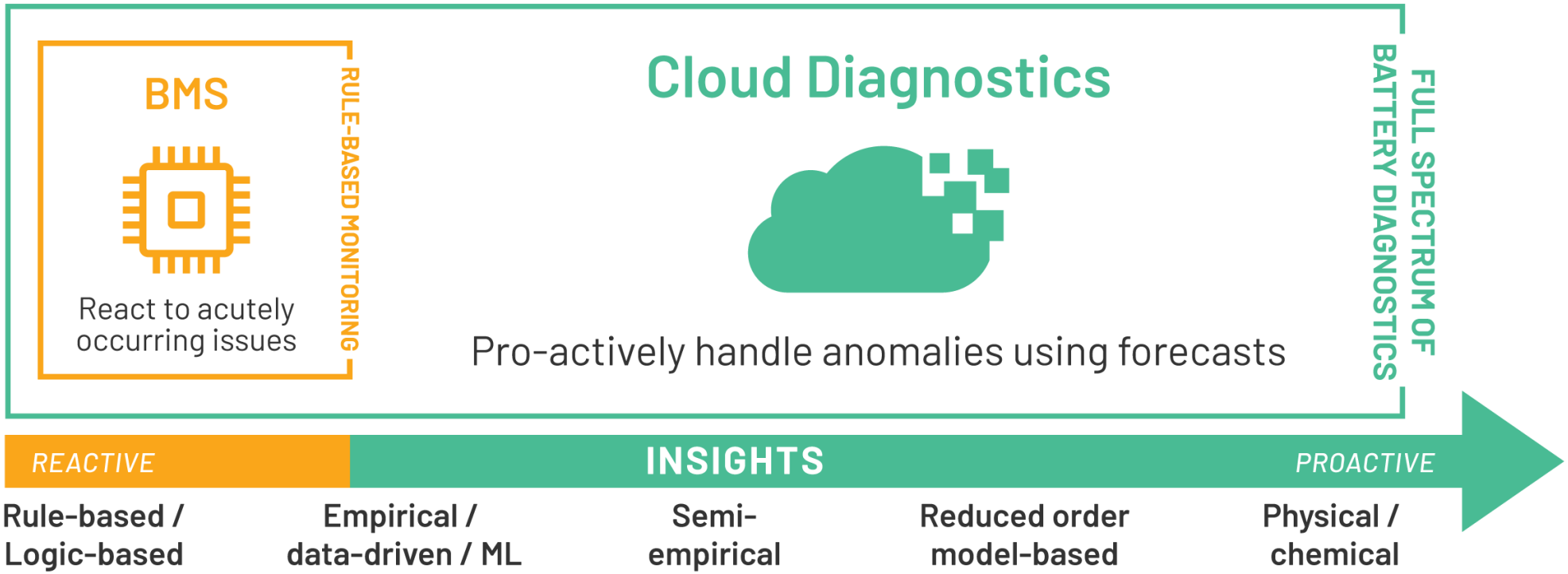
STATE OF CHARGE

Persistent SOC errors and imbalances result in lost capacity which can be regained through BMS recalibration.



PREDICTIVE ANALYTICS

Leveraging greater computing power for predictive analytics enables BESS operators to become proactive rather than reactive.



TWAICE ACCURE volytica diagnostics

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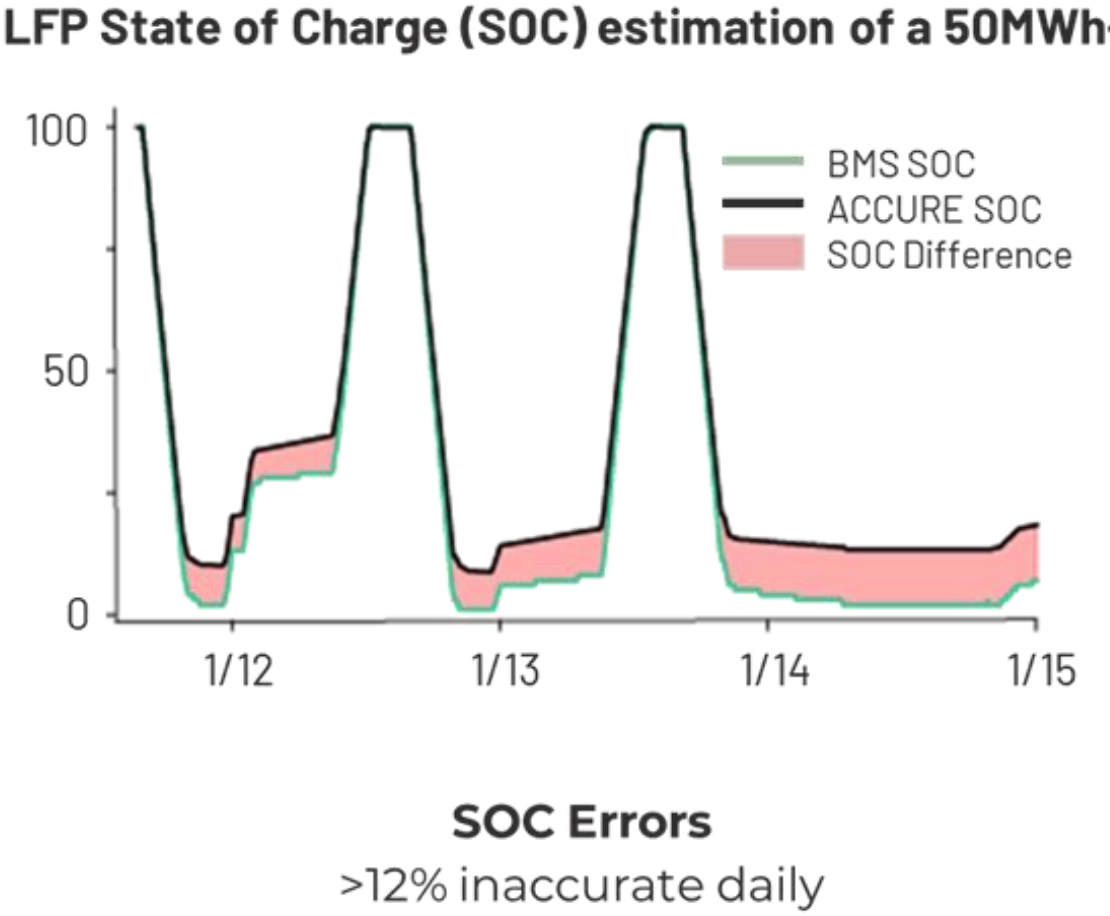
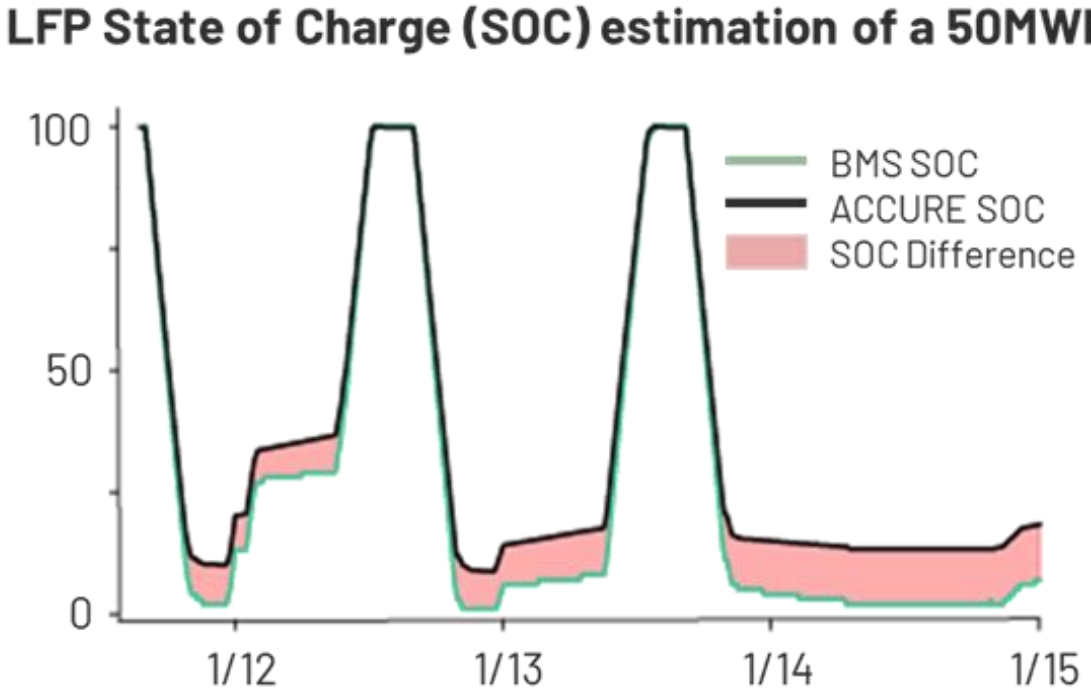


PREDICTIVE ANALYTICS

Predictive analytics can utilize multiple methods to increase the precision and accuracy of SoC calculations.



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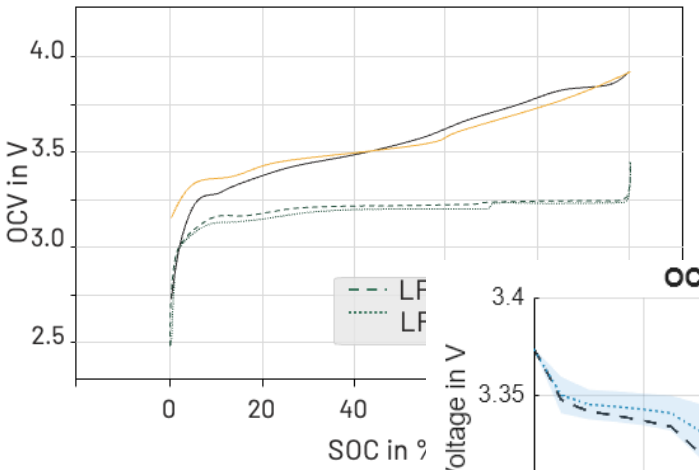
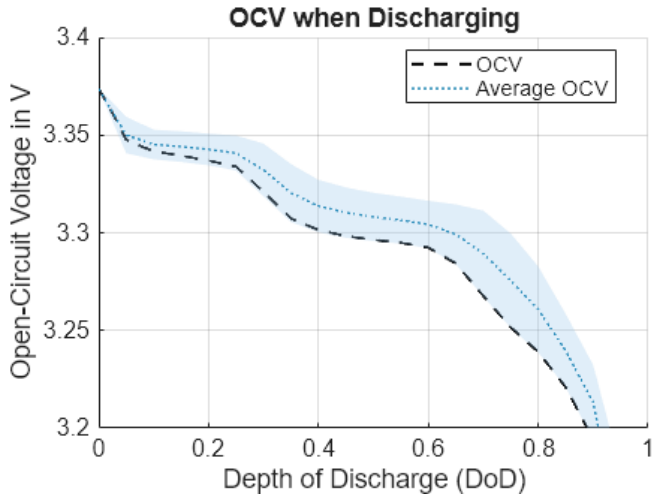


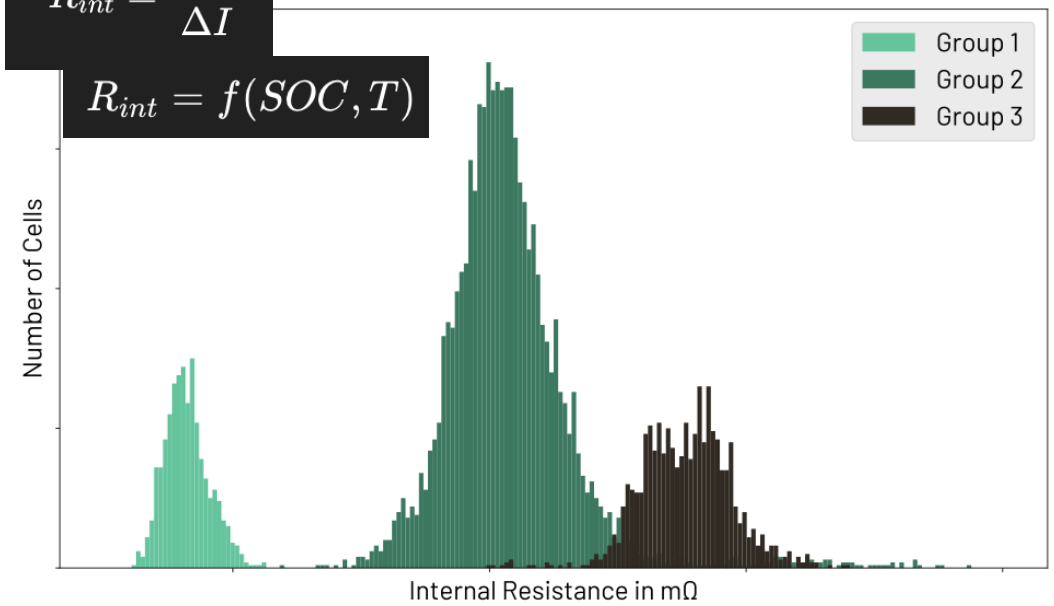


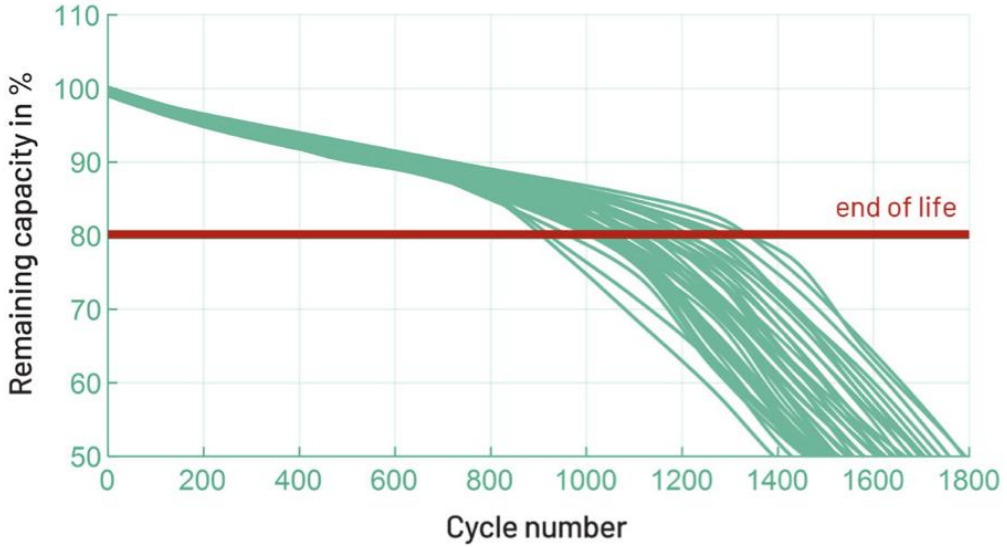
PREDICTIVE ANALYTICS

Predictive analytics can also pinpoint cell-to-cell performance differences linked to manufacturing deviations.

$$R_{int} = \frac{\Delta V}{\Delta I}$$

$$R_{int} = f(SOC, T)$$



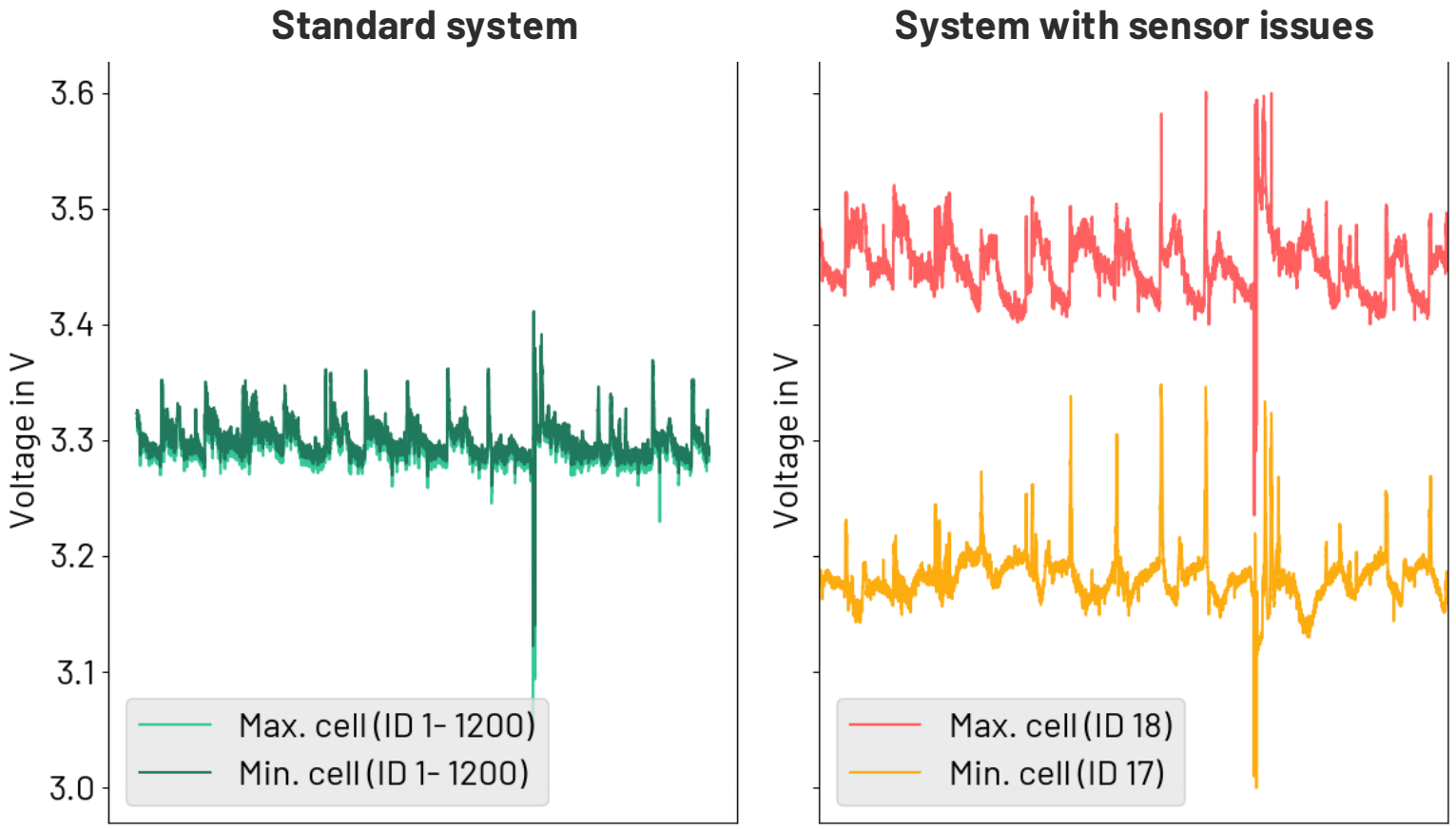


3 distinct batches of manufacturing with a large range in internal resistance

The effect of differences in manufacturing amplify as the battery ages

PREDICTIVE ANALYTICS

Still utilizing just the BMS data, predictive analytics can get insights into external stresses and other components.



PREDICTIVE ANALYTICS

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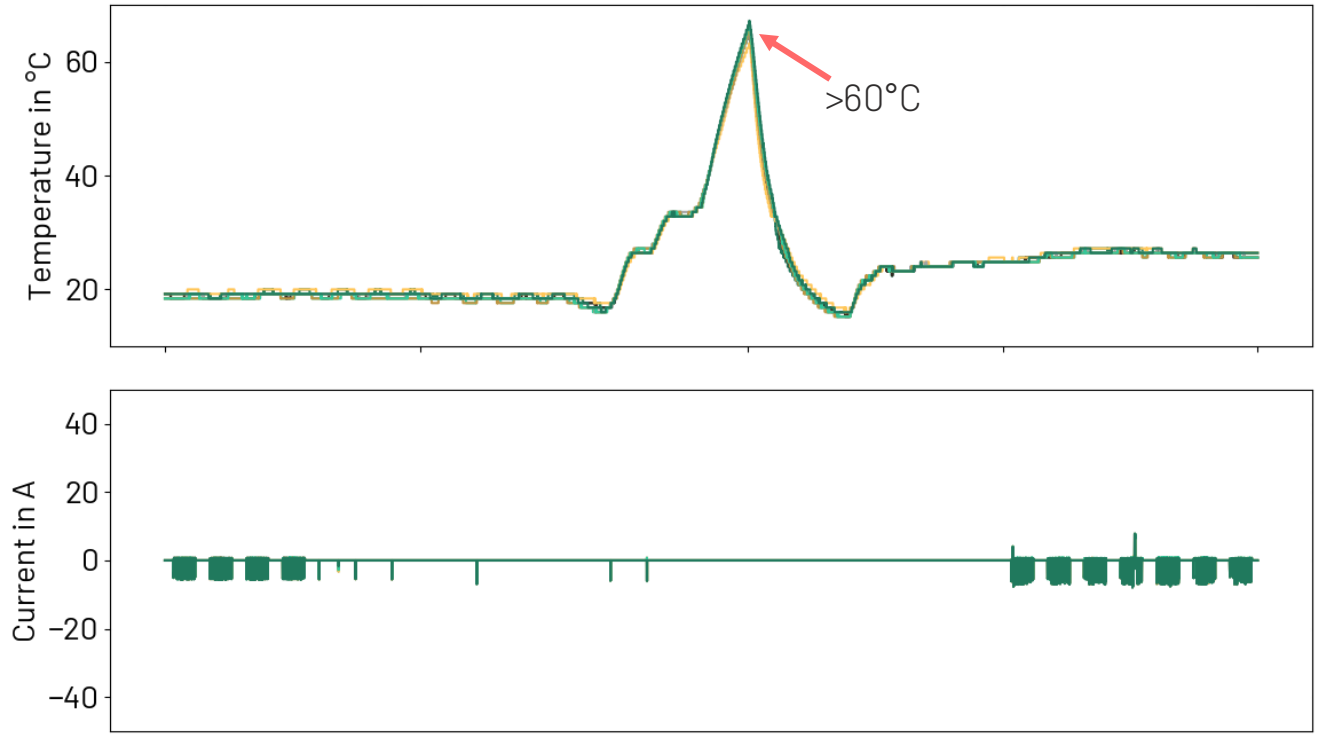
Real life situation

- High spike in temperature during commissioning
- Operational conditions voided warranty

ACCURE

- Root cause determined to be a subcontractor bringing in a dehumidifier to cover up water damage
- Litigation ongoing



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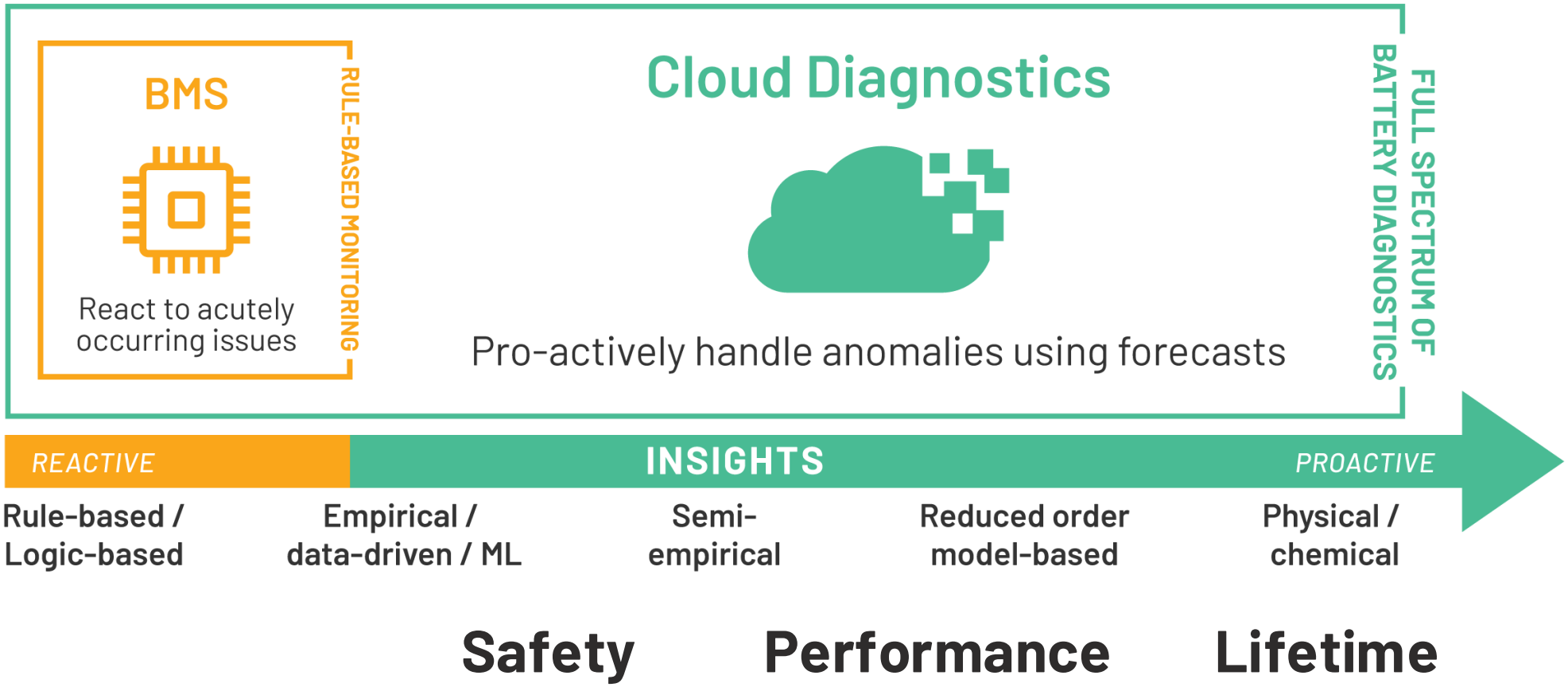
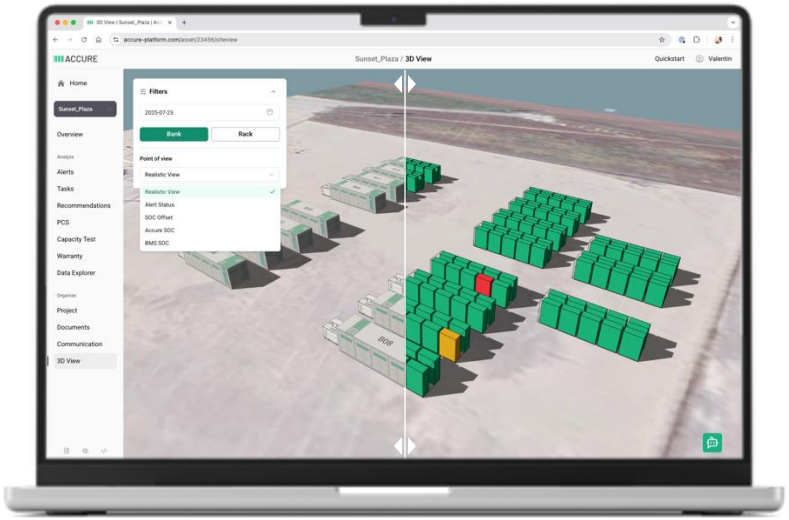


ACCURE

THE GLOBAL LEADER IN BATTERY ANALYTICS

ACCURE turns battery data into **action.**



Award-winning platform built by world-class battery experts.

PREDICTIVE ANALYTICS

ACCURE turns the battery data you already collect into measurable **revenue gains and OPEX savings**

ASSET OPTIMIZATION

+6% more available MWh by reversing SoC imbalance

+11% trading revenue from accurate, real-time SOC

Decrease in unplanned downtime

CLAIMS AND COMPLIANCE

100% of warranty cases claimable with data backed evidence meet every OEM and insurer requirement

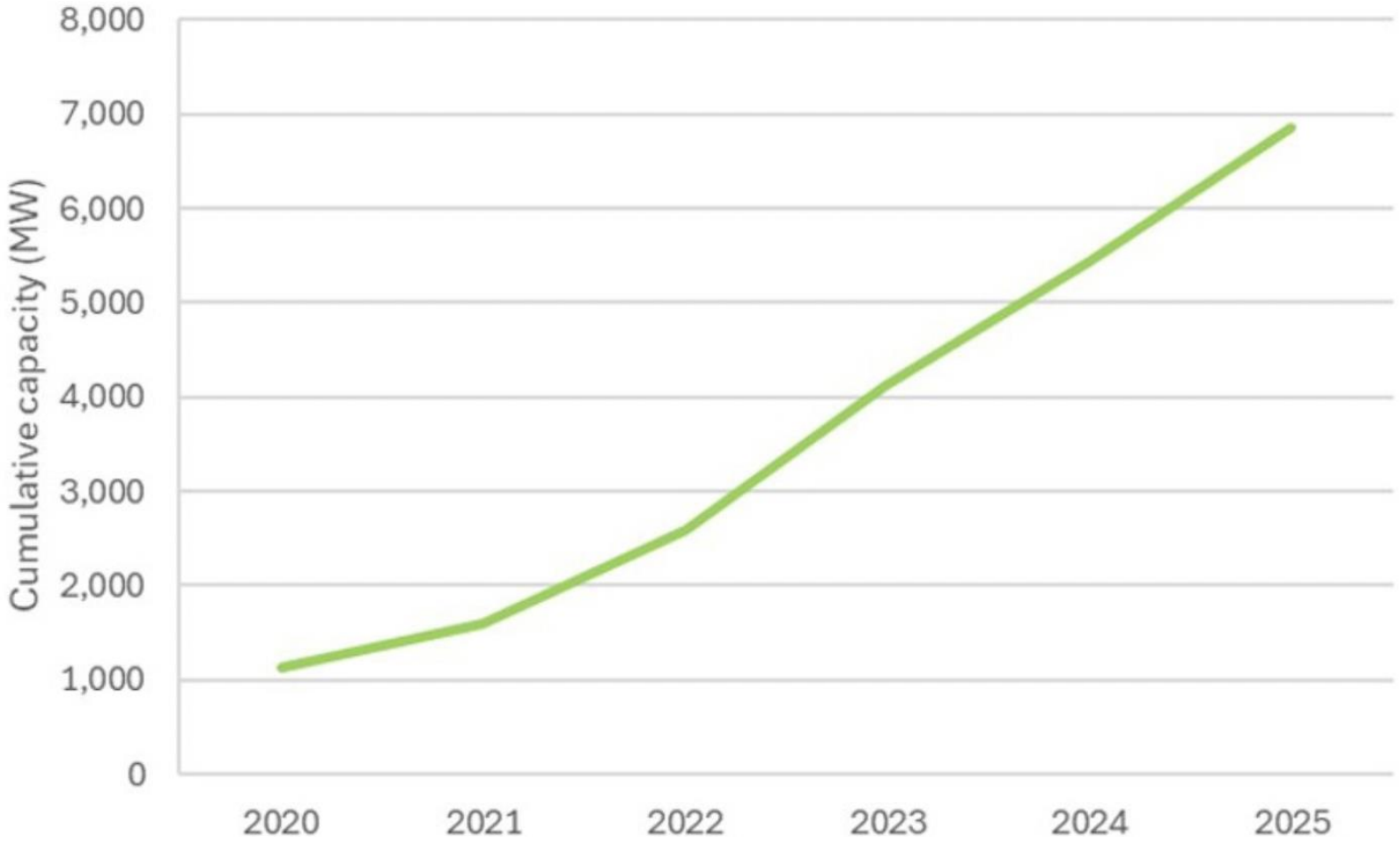
OPERATIONAL EXCELLENCE

98% reduction in incident risk and 25% less asset manager effort

One FTE can actively manage and optimize multi-vendor fleets

CONCLUSION

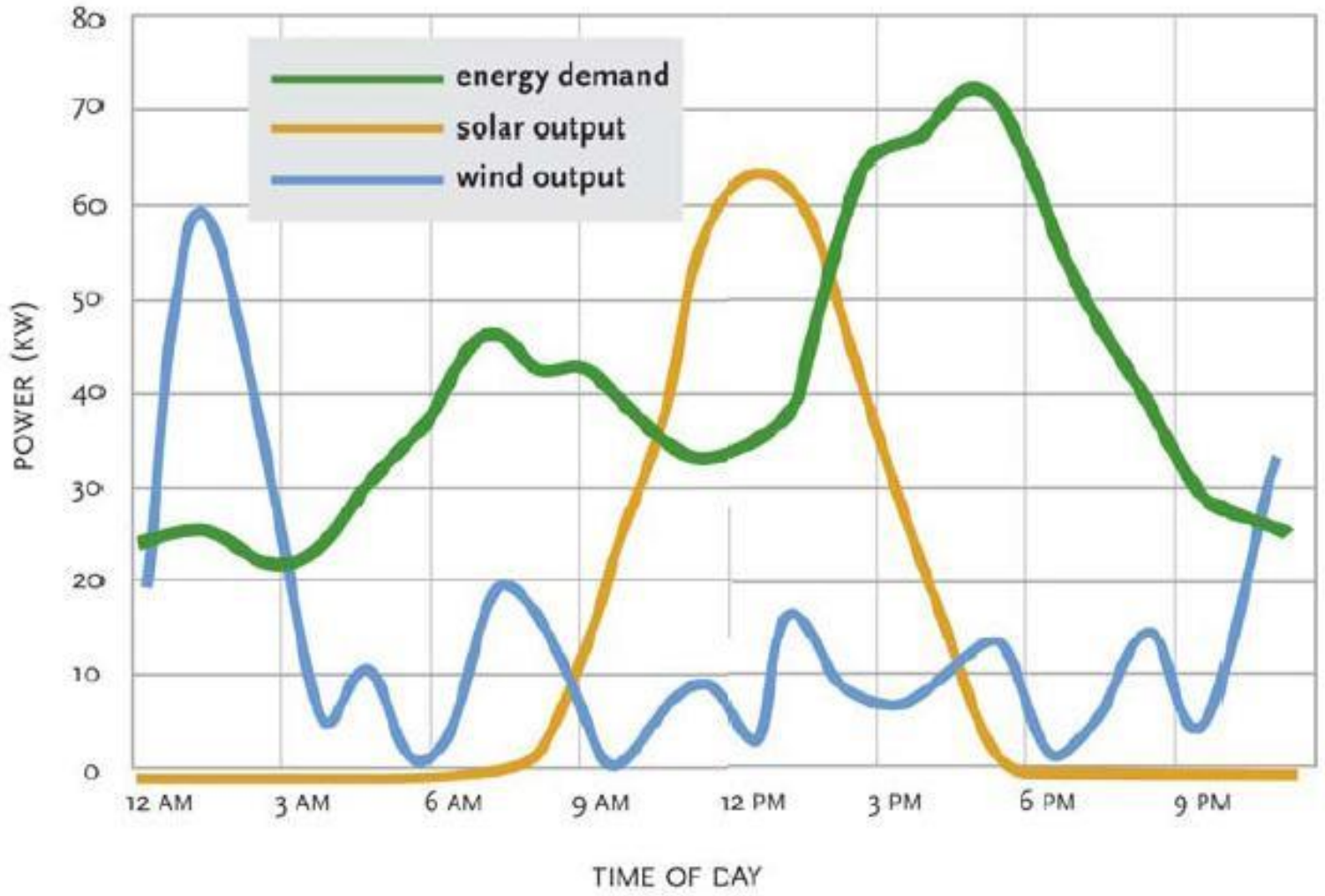
BESS cumulative capacity in the UK has grown 7-fold since 2020 reaching ~7GW in 2025



Sutherland, EnergyPulse
RenewableUK 2025

CONCLUSION

Renewable generation loads do not match the energy demand thus the grid requires load shifting



Edrisian et. al, 2013

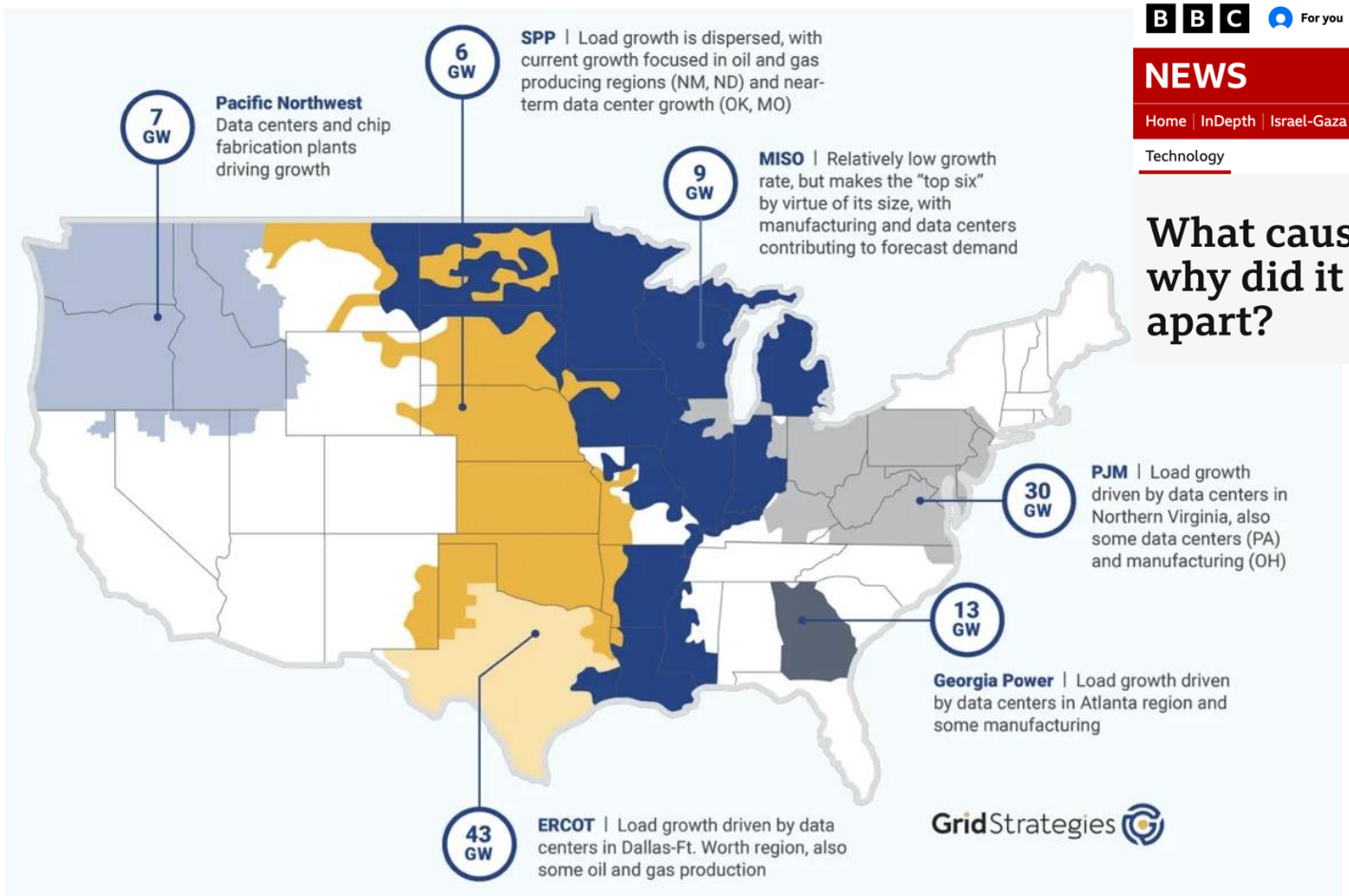
CONCLUSION

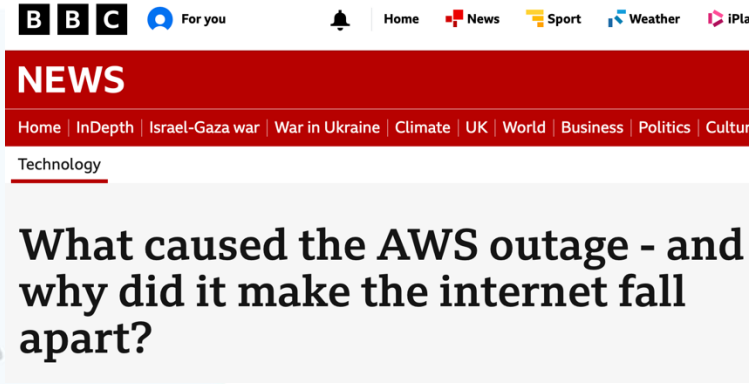
Voltage instability triggered in the 2025 Iberian blackout – batteries can be a solution but only if they can operate when needed most!

Metro UK, 2025

CONCLUSION

Data centers need consistent load – integration of batteries can be a solution but only if they can operate when needed most!

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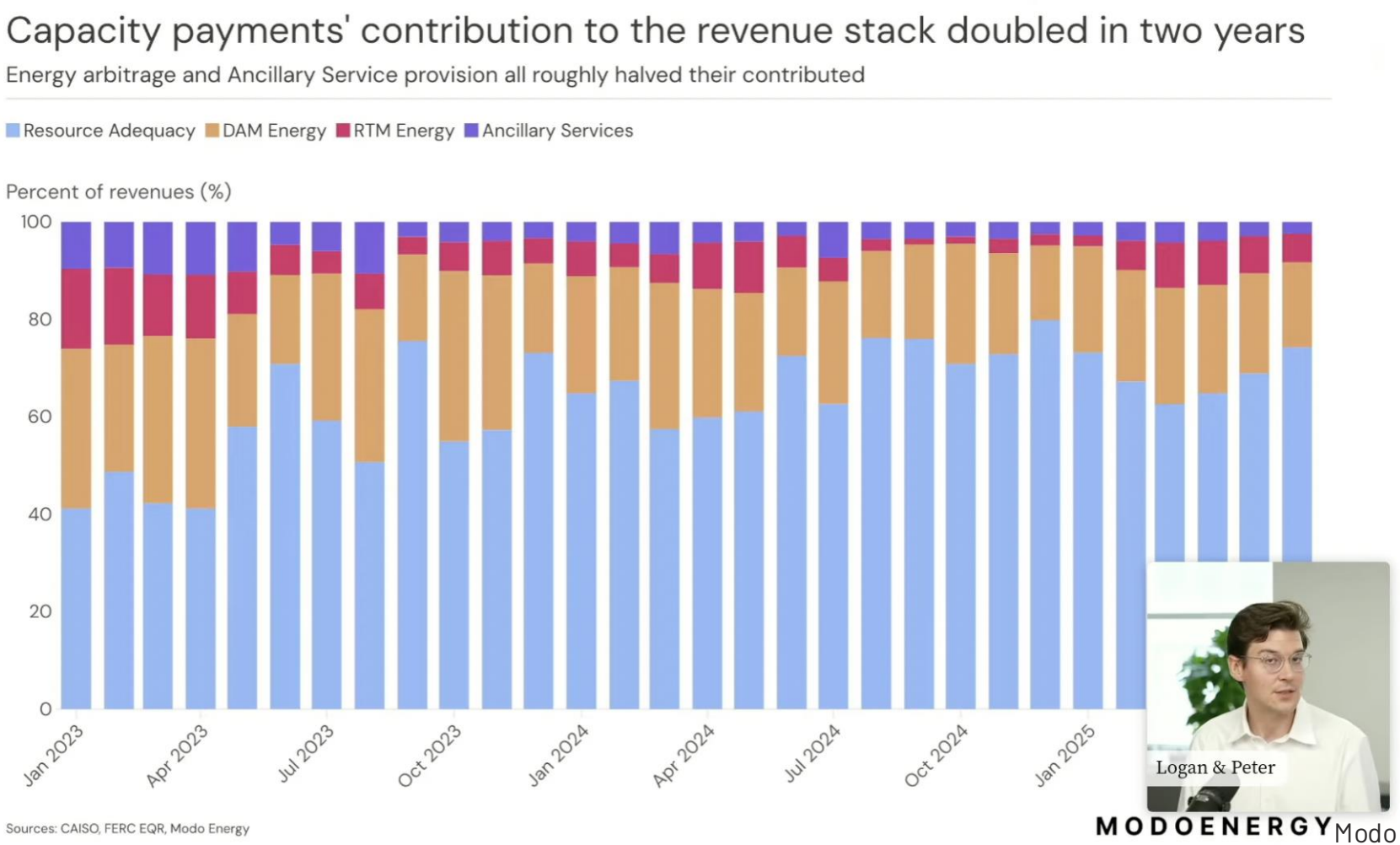
Technology

What caused the AWS outage - and why did it make the internet fall apart?

Grid Strategies, 2025

CONCLUSION

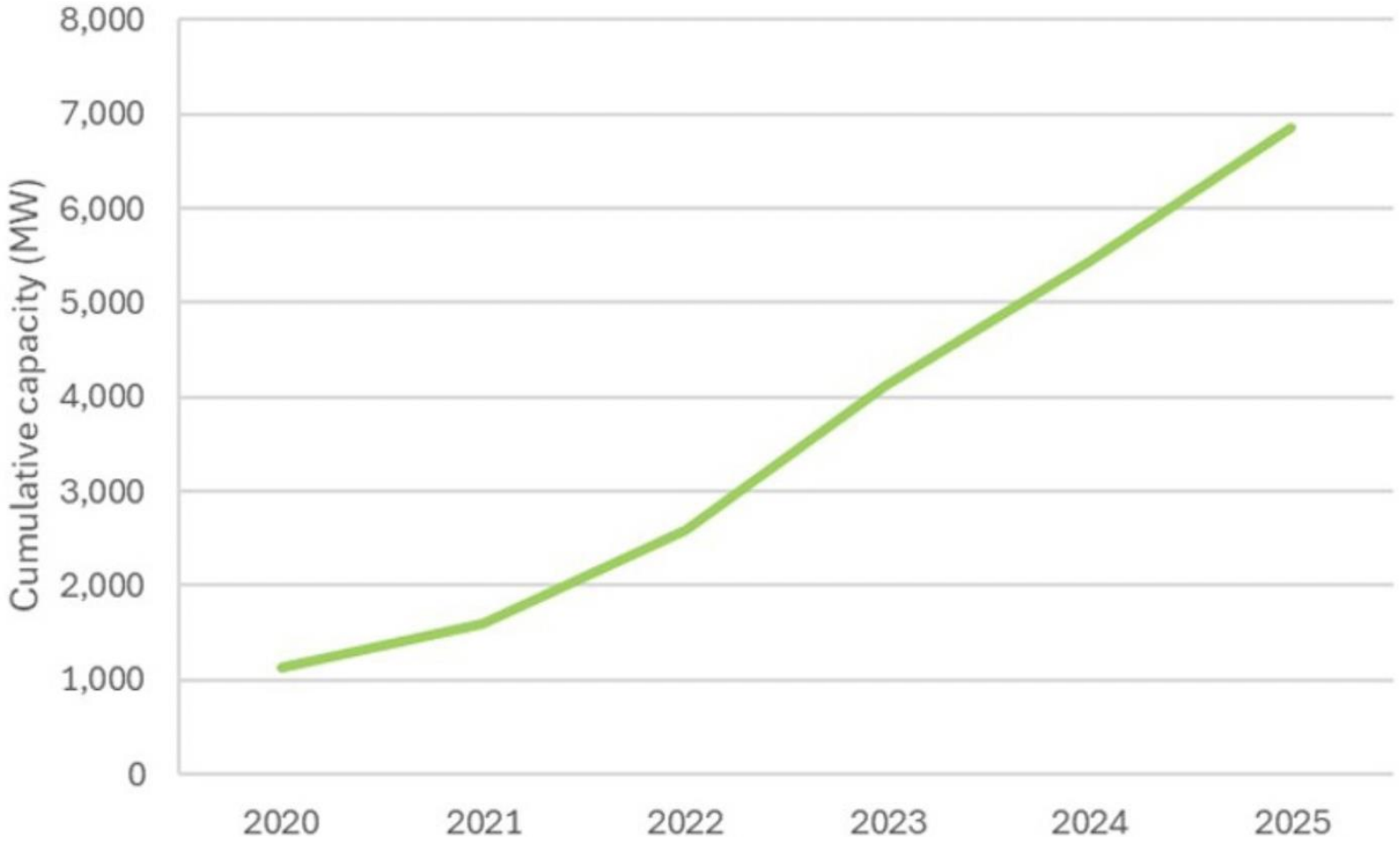
BESS assets are revenue stacking – improving availability & trading improves ROI by decreasing risk & increasing profitability



MODOENERGY Modo Energy CAISO, 2025

CONCLUSION

BESS cumulative capacity in the UK has grown 7-fold since 2020 reaching ~7GW in 2025



Sutherland, EnergyPulse
RenewableUK 2025

INTRODUCTION

Still a California kid at heart, Liz Oliphant aims to utilize technology, data, and knowledge sharing to conserve nature!

FULBRIGHT

UNIVERSITY OF MICHIGAN

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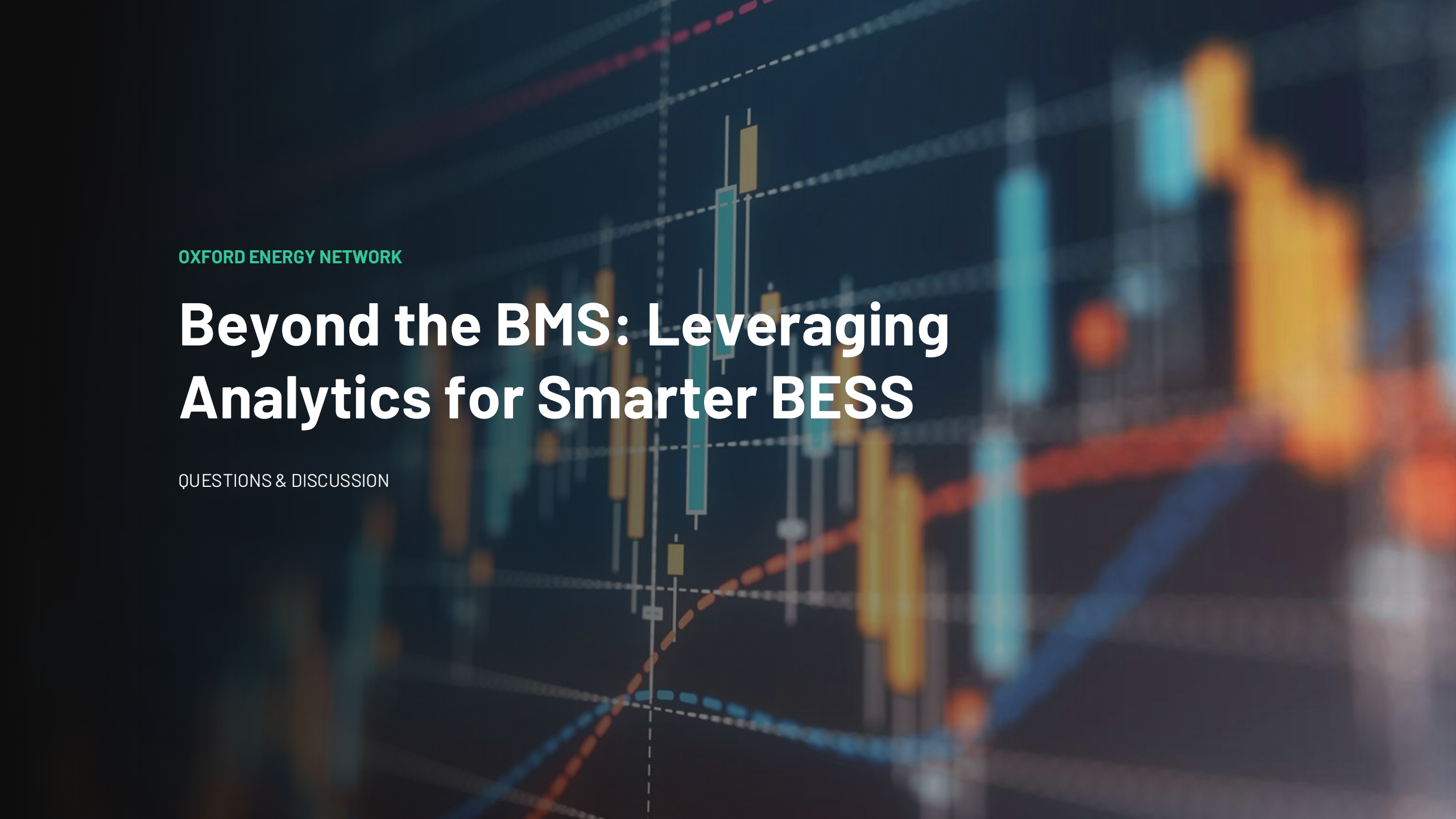
APRICUM

ACCURE
Battery Intelligence



OXFORD ENERGY NETWORK

Beyond the BMS: Leveraging Analytics for Smarter BESS

QUESTIONS & DISCUSSION