

BVRLA  
**Fleets  
in  
Charge**  
**DEEP DIVE**

**Battery Health:  
Supercharge your  
knowledge**



**Chancery Lane, London  
16 May 2023**

[bvrla.co.uk/fleetsincharge](https://bvrla.co.uk/fleetsincharge)

In partnership with  **AutoTrader**

# Competition Law Do's and Don'ts



## DO NOT

- Discuss individual company prices, price changes, terms of sale and profit margins.
- Discuss information as to future plans of individual companies, production, distribution or marketing plans, including proposed new territories or customers.
- Discuss matters relating to individual suppliers or customers or any commercially sensitive information.



## BE WARY

### YOU MUST SEEK ADVICE IF:

- You receive information from another competitor, or are asked to provide information, that you believe is confidential or commercially sensitive.

### ALWAYS:

- Ensure a detailed agenda is circulated in advance and are followed closely and minutes of the meeting are recorded and kept.
- Begin the meeting with the reminder that the attendees should not discuss commercially sensitive information under any circumstances.
- Be prepared to halt a meeting if conversations cross into potentially unlawful territory.



## NO PROBLEM

- Discussion on any matter relating to the aims and objectives of the committee – for example issues of law and policy affecting the industry.
- Discussing BVRLA policies, lobbying tactics & strategies, and other BVRLA activities.
- Discussing information about industry activities obtained from third parties or other media sources provided the availability of the information has not been arranged with a competitor.
- Discussion with other trade bodies or organisations which will be of general benefit to the industry.

# Agenda

10:00	<b>Welcome</b>	Toby Poston, BVRLA
10:05	<b>Keynote: Battery Chemistry</b>	Dr Billy Wu
10:35	<b>Panel: Battery Degradation</b>	Chair: Marc Palmer, Autotrader Panellists: Scott Raffan, Geotab; Dr Matt Stock, Innovate UK and Gavin White, About: Energy
11:20	<b>Tea/Coffee Break</b>	
11:35	<b>Department for Transport</b>	Adam Dack
12:05	<b>EV Consumer Landscape</b>	Marc Palmer, Autotrader
12:25	<b>Panel: Battery Health Certificates</b>	Chair: Catherine Bowen, BVRLA Panellists: Thomas Mulon, MOBA; Tobias Huelsing, Bosch; Patrick Cresswell, ClearWatt; James Wallace, Elysia Battery Intelligence from WAE and Alex Johns, Altelium
11:30	<b>Closing Comments</b>	Toby Poston, BVRLA

Imperial College  
London

# The life and death of lithium-ion batteries

*How long do they last?*

Dr. Billy Wu

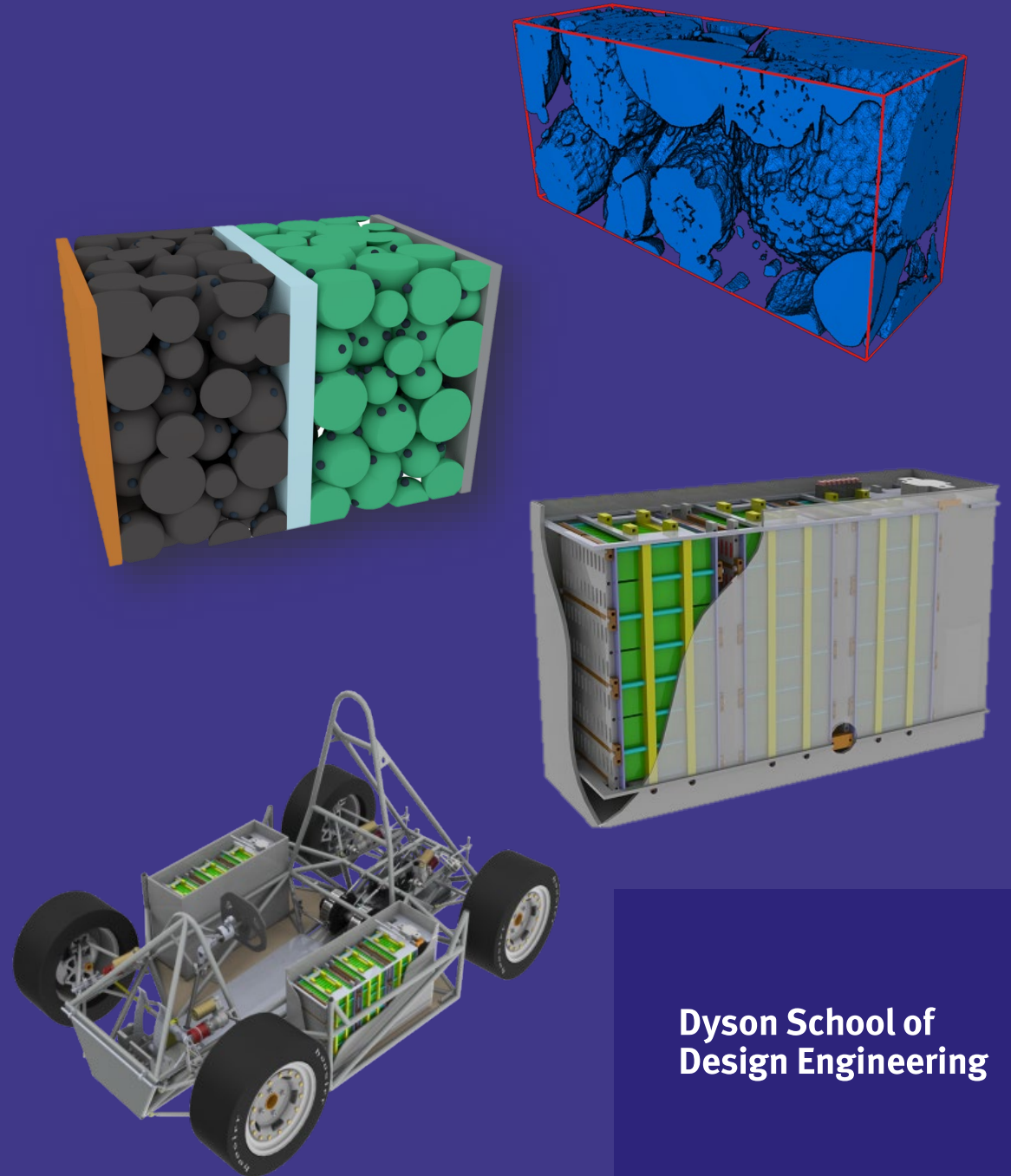
Senior Lecturer (Associate Professor)

Dyson School of Design Engineering

Imperial College London

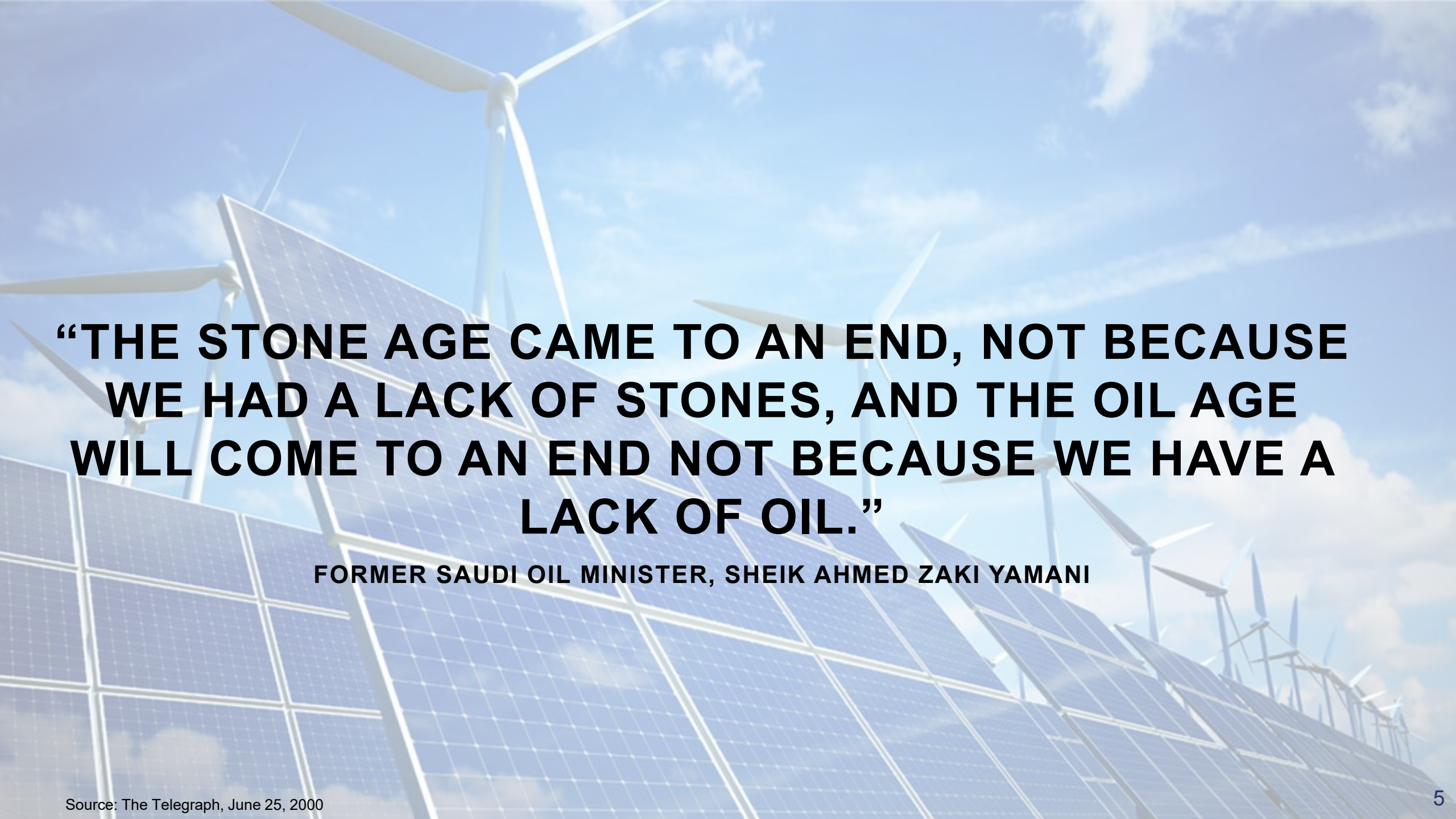
[billy.wu@imperial.ac.uk](mailto:billy.wu@imperial.ac.uk)

Twitter - [@ICBillyWu](https://twitter.com/ICBillyWu)



**Dyson School of  
Design Engineering**





**“THE STONE AGE CAME TO AN END, NOT BECAUSE WE HAD A LACK OF STONES, AND THE OIL AGE WILL COME TO AN END NOT BECAUSE WE HAVE A LACK OF OIL.”**

**FORMER SAUDI OIL MINISTER, SHEIK AHMED ZAKI YAMANI**

# Inevitable transition to electric vehicles

BBC Account Home News Sport Weather iPlayer Sounds CBBC

**NEWS**

Home | Coronavirus | US Election | UK | World | Business | Politics | Tech | Science | Health | Family & Education

World | Africa | Asia | Australia | Europe | Latin America | Middle East | US & Canada

## France set to ban sale of petrol and diesel vehicles by 2040

© 6 July 2017

BBC Account Home News Sport Weather

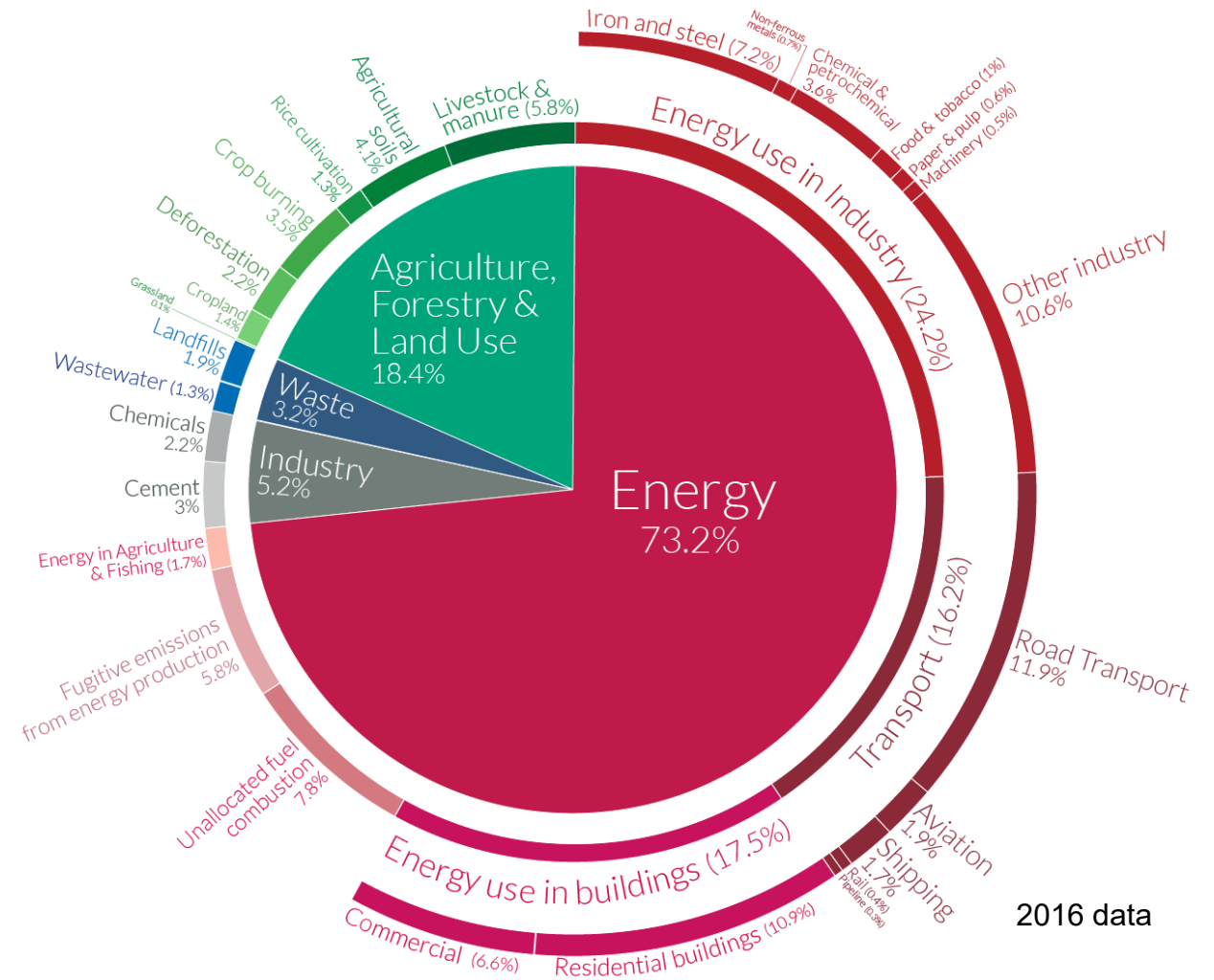
**NEWS**

Home | Brexit | Coronavirus | UK | World | Business | Politics | Tech | Science | Health

Science & Environment

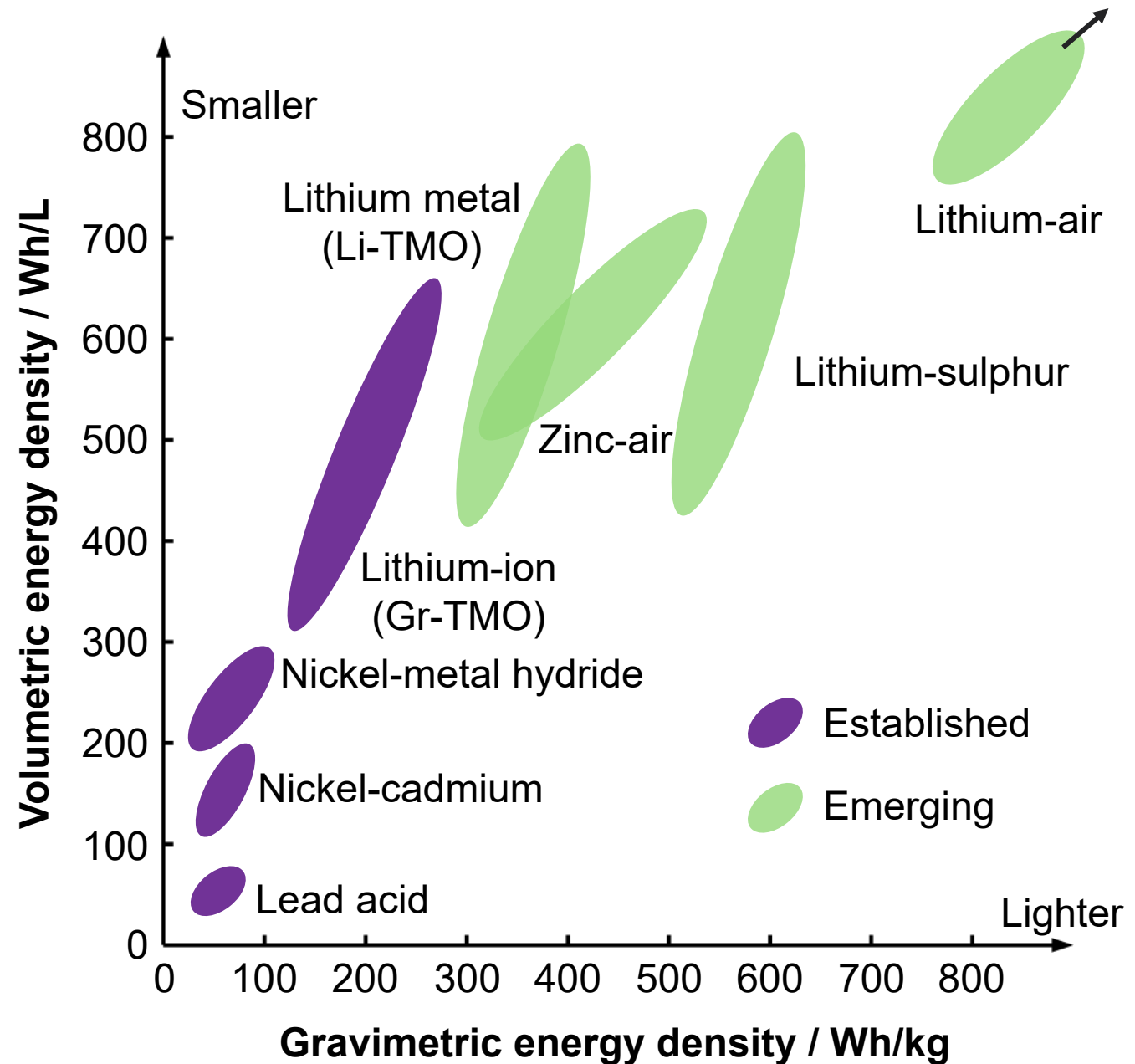
## Ban on new petrol and diesel cars in UK from 2030 under PM's green plan

Global greenhouse gas emissions by sector (~50 billion tonnes CO<sub>2</sub>eq.)



# Battery technologies

- Petrol ~9,500 Wh/L and ~12,800 Wh/kg
  - Engine efficiency ~25%
  - ~2,400 Wh/L and ~3,200 Wh/kg
- Lots of different chemistries which are defined by their cathode/anode materials
  - Lead acid
  - Nickel-cadmium
  - Nickel-metal hydride
  - Lithium-ion
    - Graphite-Transition Metal Oxide
  - Lithium metal
    - Lithium-Transition Metal Oxide
  - Lithium-sulphur
  - Metal-air



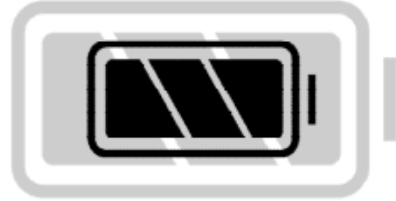
# Significant improvements needed

## Cost



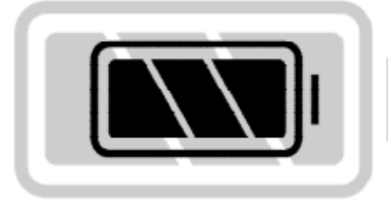
Now 130\$/kWh (cell)  
280\$/kWh (pack)  
Future 50\$/kWh (cell)  
100\$/kWh (pack)

## Energy density



Now 700 Wh/L  
250 Wh/kg (cell)  
Future 1400 Wh/L  
500 Wh/kg (cell)

## Power density



Now 3 kW/kg (pack)  
Future 12 kW/kg (pack)

## Safety



Future eliminate thermal runaway at pack level to reduce pack complexity

## 1<sup>st</sup> life



Now 8 years (pack)  
Future 15 years (pack)

## Temperature



Now -20° to +60°C (cell)  
Future -40° to +80°C (cell)

## Predictability



Future full predictive models for performance and aging of battery

## Recyclability



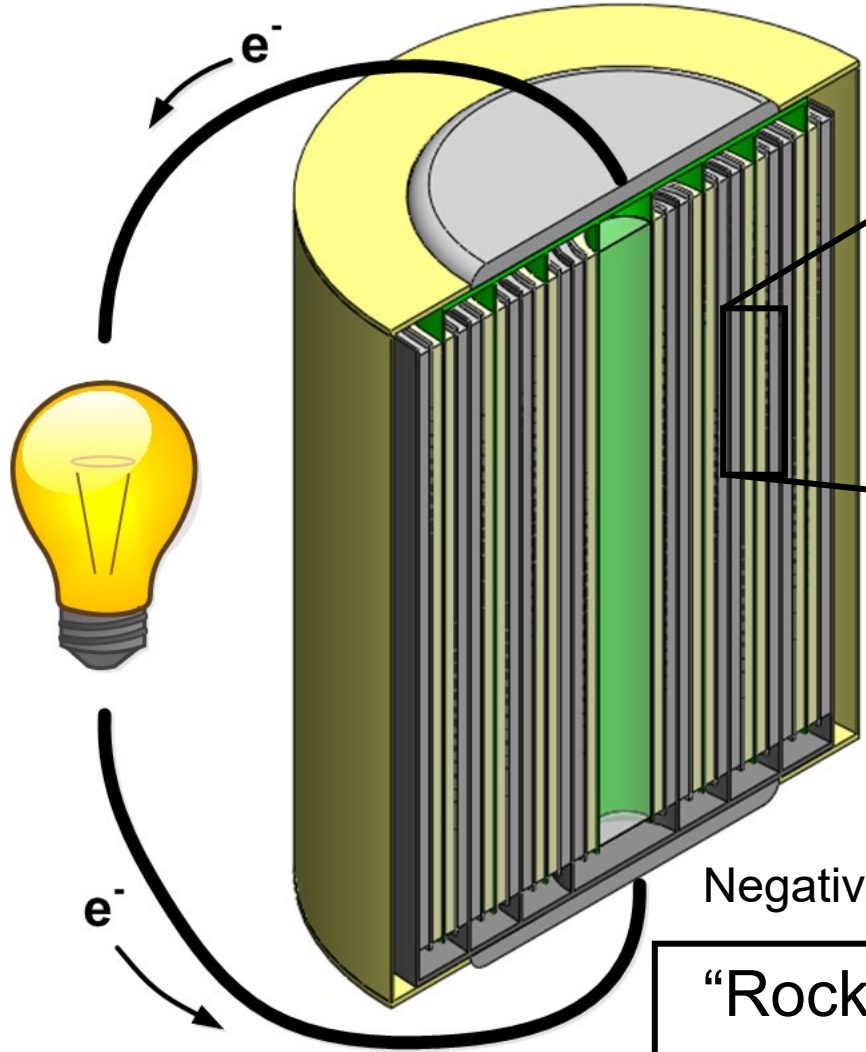
Now 10-50% (pack)  
Future 95% (pack)

Faraday Institution targets



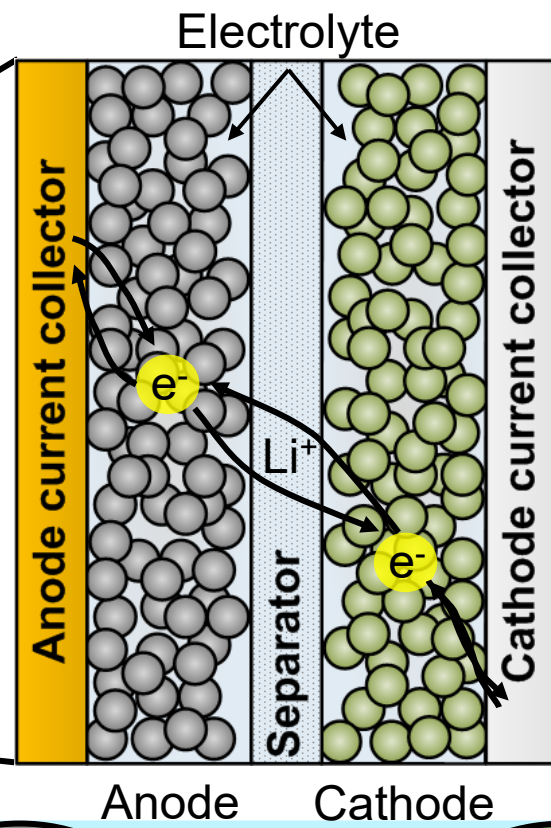
# How does a battery work?

Positive terminal



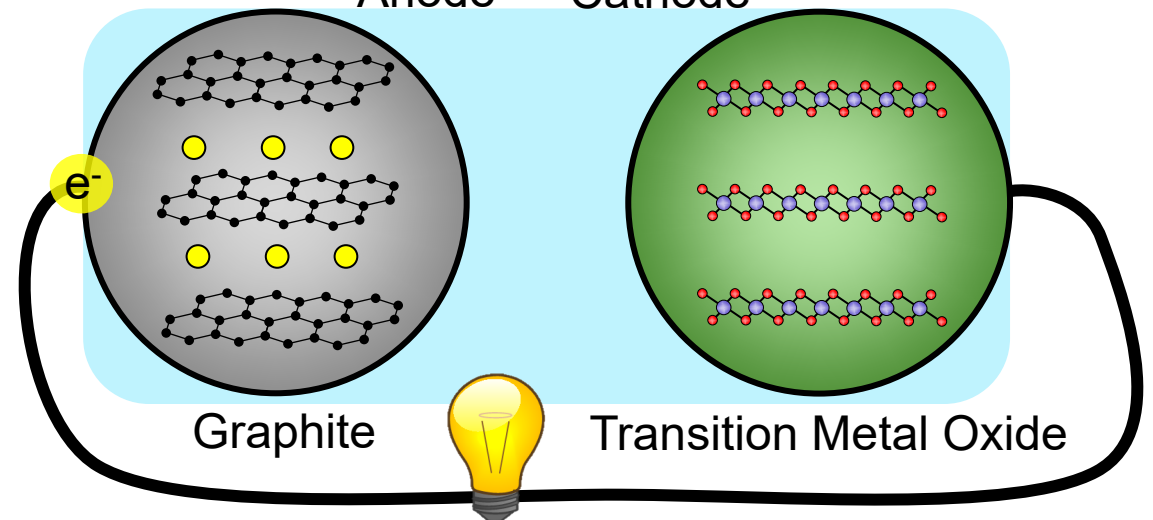
Negative terminal

“Rocking chair”  
mechanism



Anode

Cathode



Graphite

Transition Metal Oxide

# Do we have good chemistry?

## Design objective

### Anode

High capacity and low voltage

### Cathode

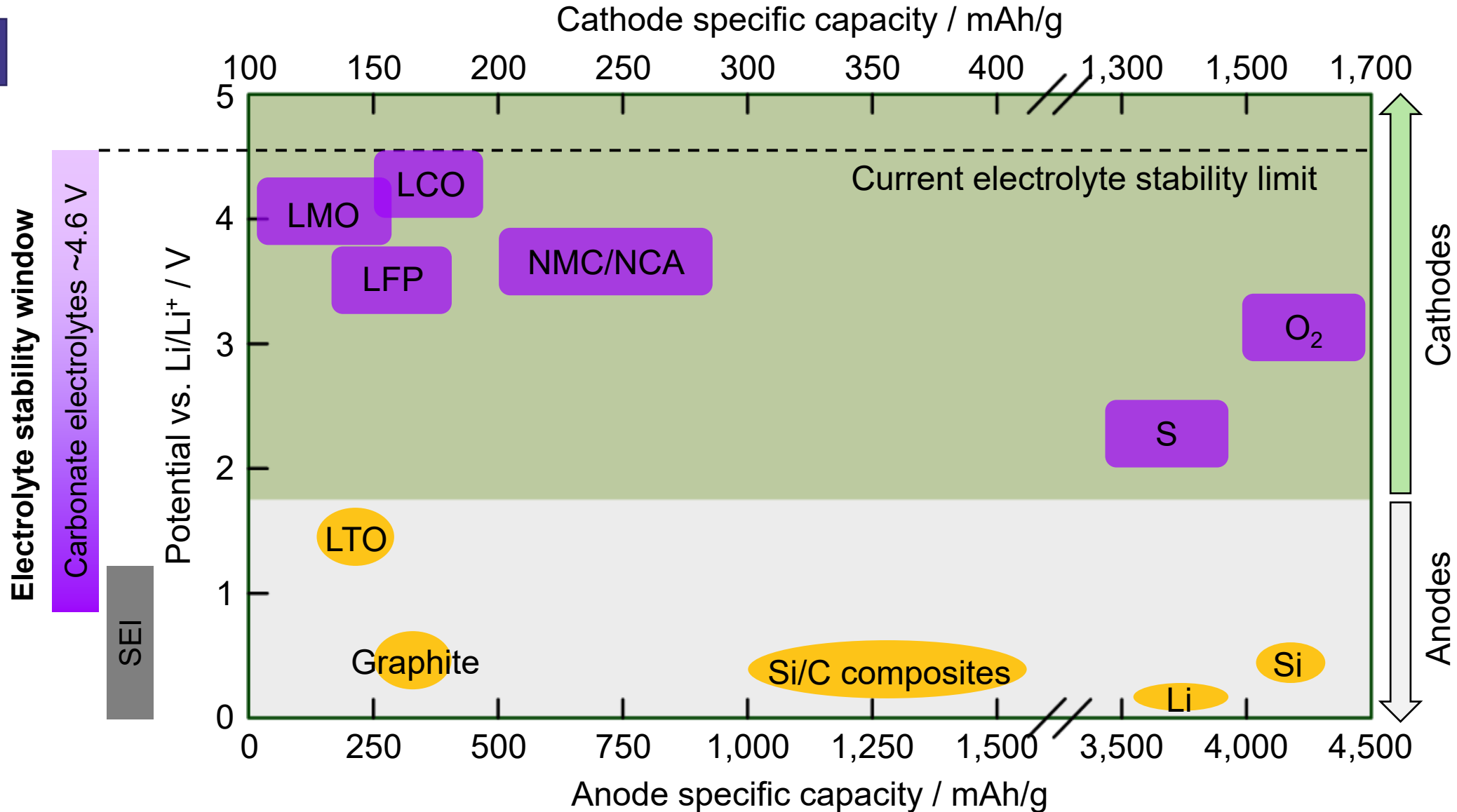
High capacity and high voltage

### Electrolyte

Large stability window

### All

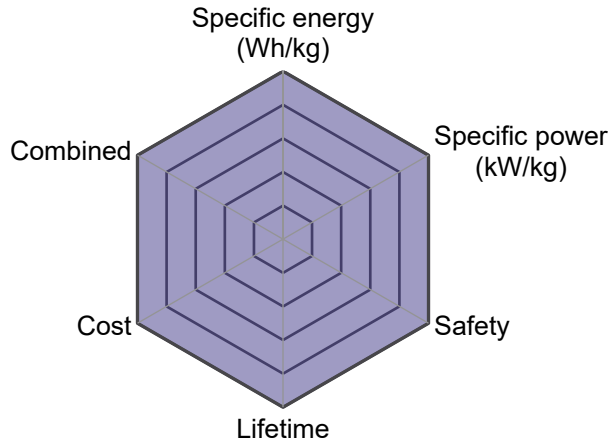
Cheap, mass produced, non-flammable



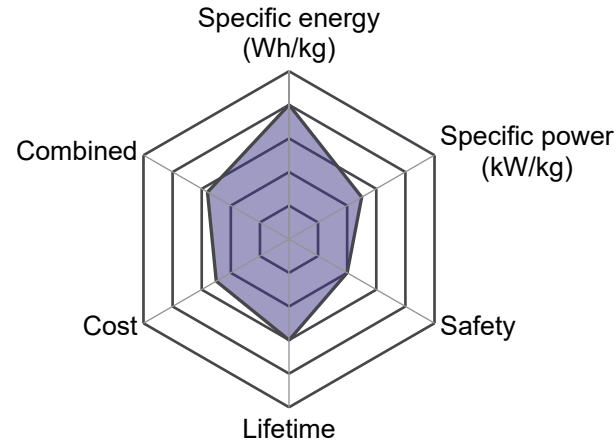
# Do we have good chemistry?

**Nickel = Capacity**  
**Cobalt = Rate capability (power), stability**  
**Manganese = Safety, cost**

## The perfect cathode

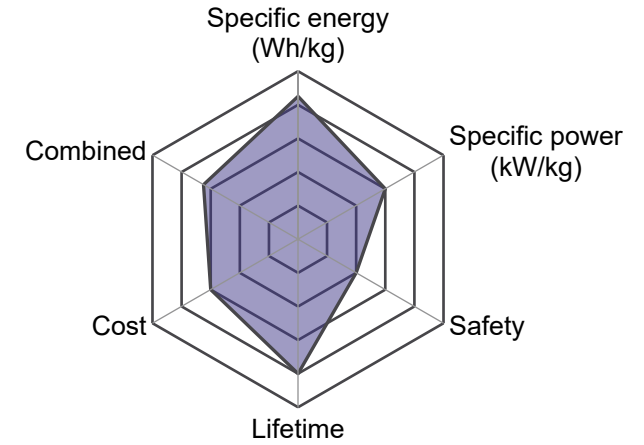


## NMC

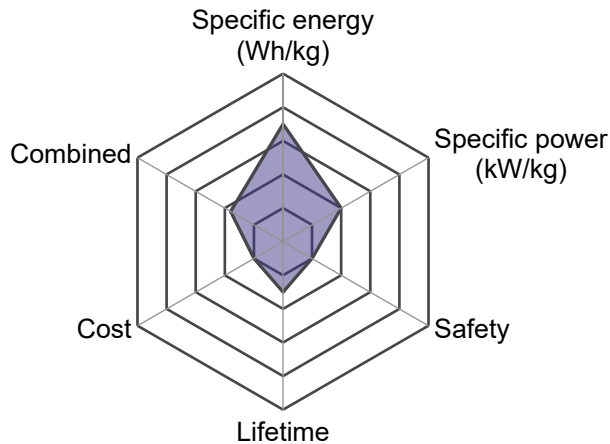


Increasing nickel  
content trend  
continues

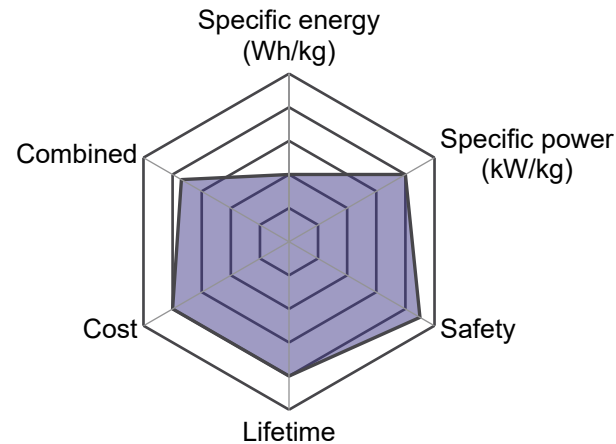
## NCA



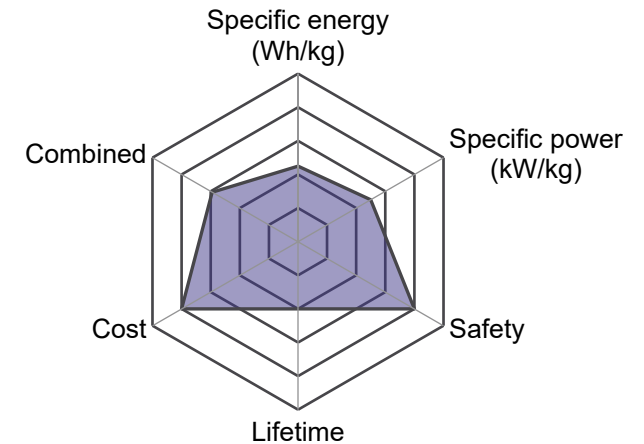
## LCO



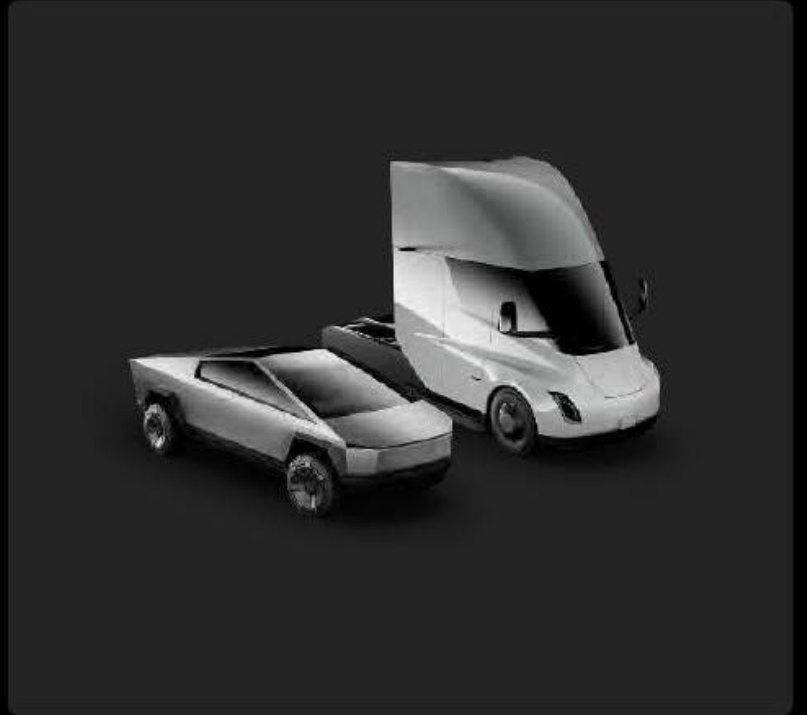
## LFP



## LMO



\*Not to scale



**IRON BASED**  
LONG CYCLE LIFE

**NICKEL + MANGANESE**  
LONG RANGE

**HIGH NICKEL**  
MASS SENSITIVE

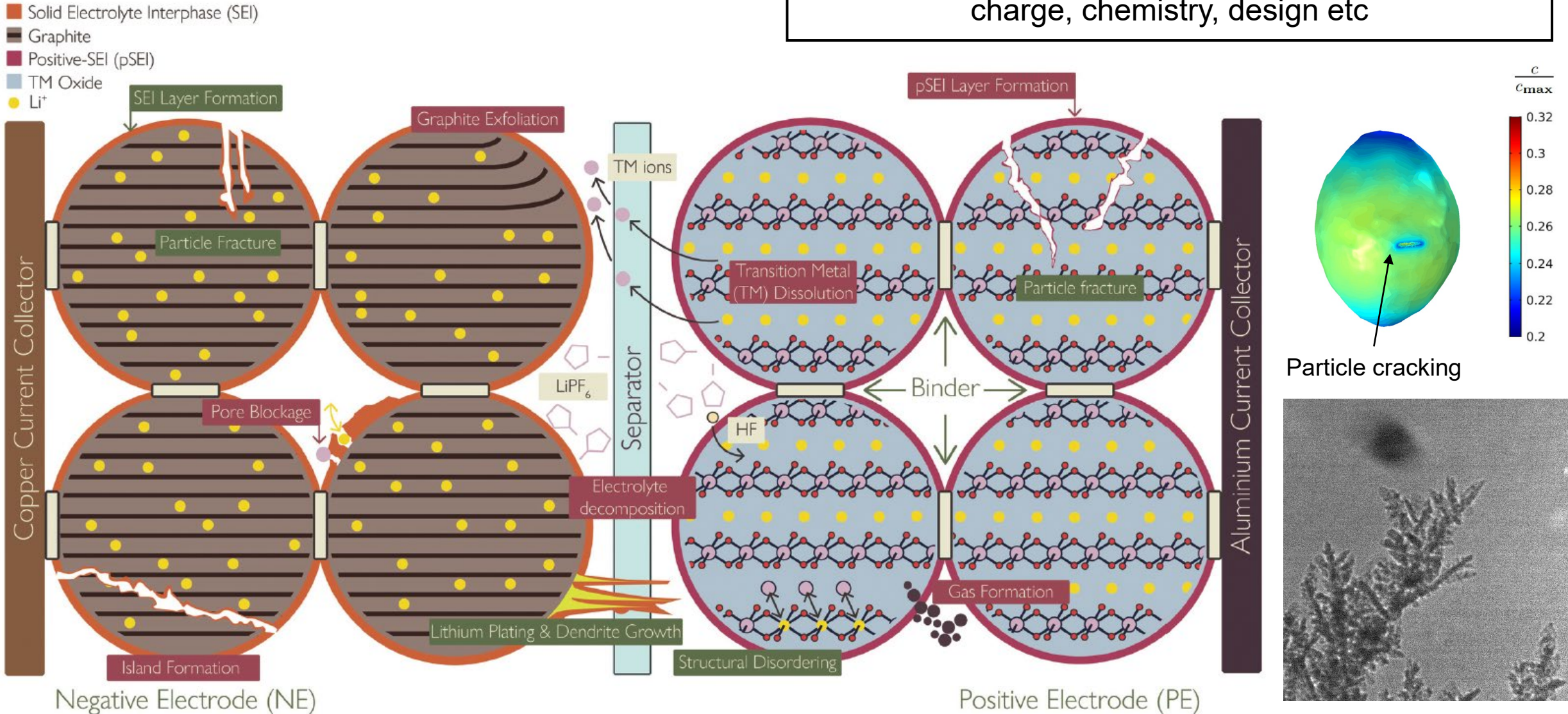
# Not a 1 size fits all solution

Tesla battery day 2020



# Degradation mechanisms

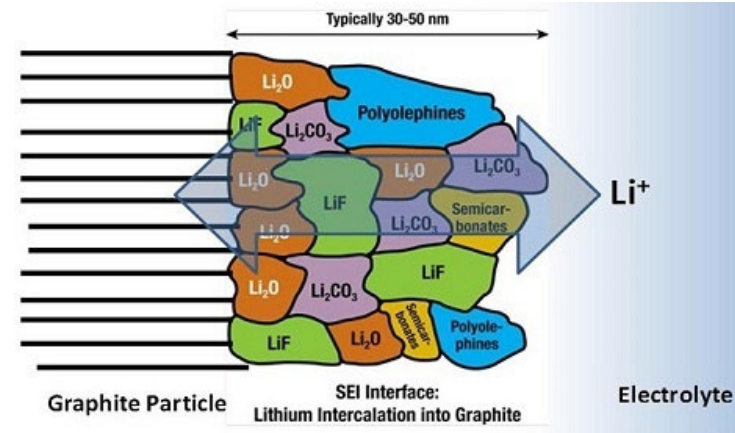
Degradation in batteries is complex and depends on a range of factors: temperature, current, state-of-charge, chemistry, design etc



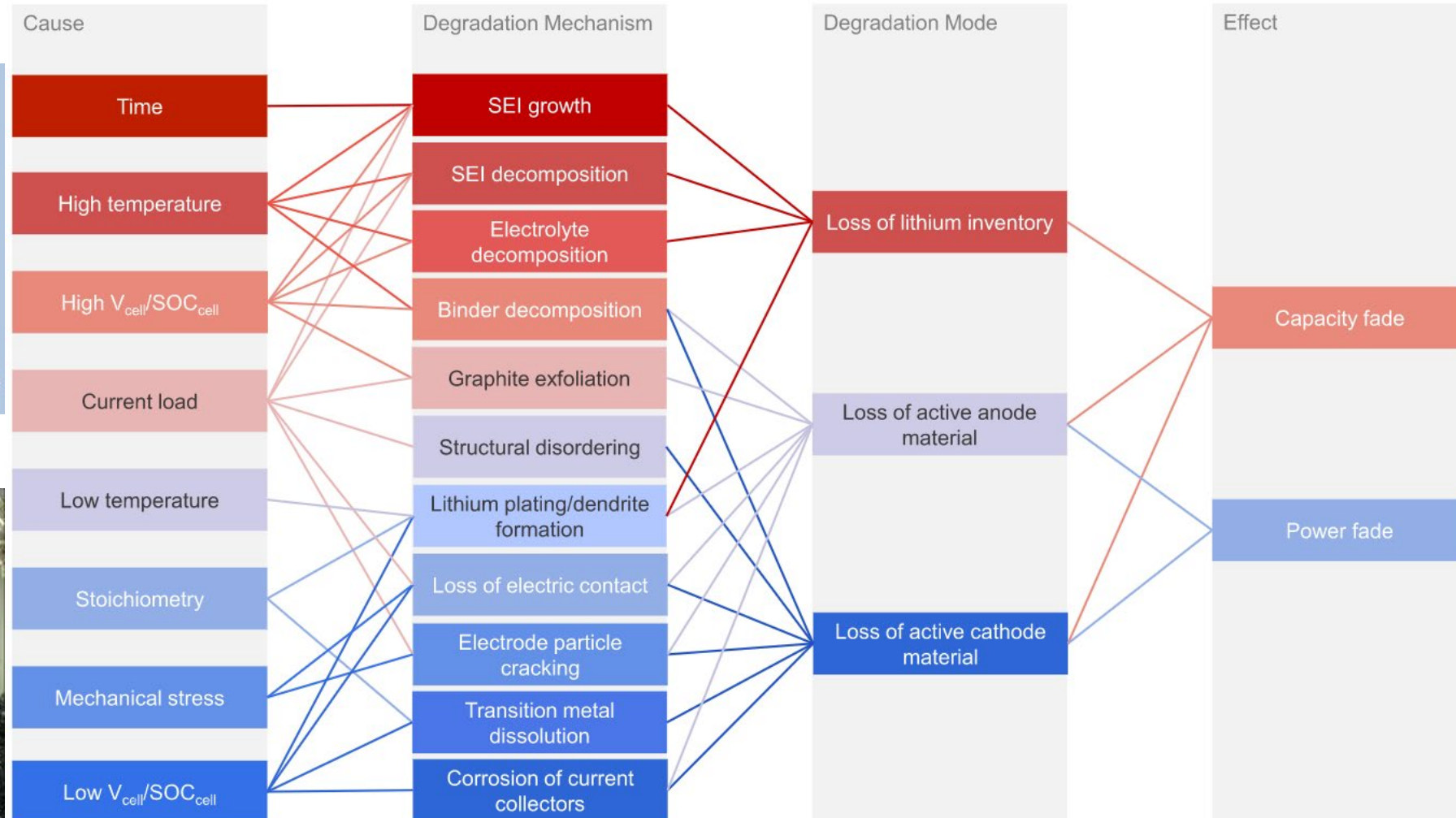


# Degradation modes in lithium-ion batteries

SEI layer=Passivation layer



Lithium dendrites=Short circuiting



Battery degradation is path dependent;  $A+B=C$  but  $B+A \neq C$

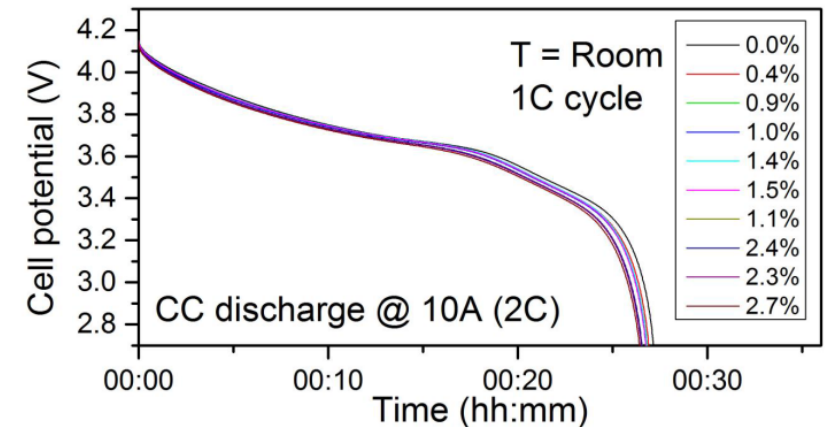
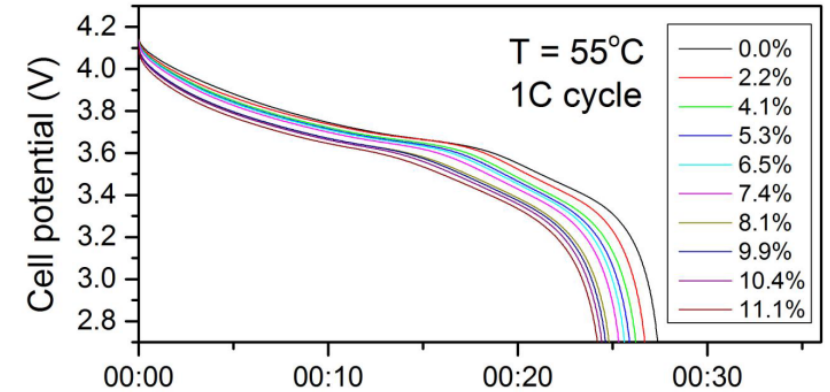
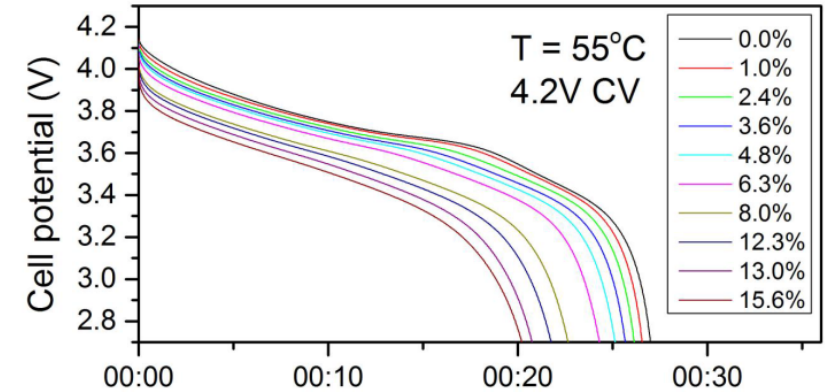
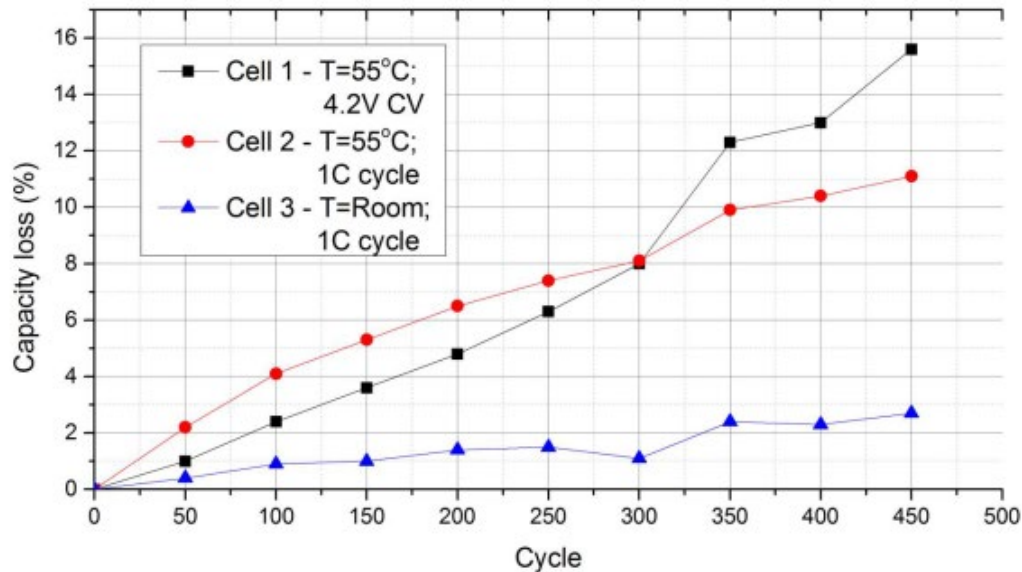
# How do we define state-of-health?

$$SOH_{Capacity} = \frac{\text{Current capacity (Ah)}}{\text{Initial capacity (Ah)}}$$

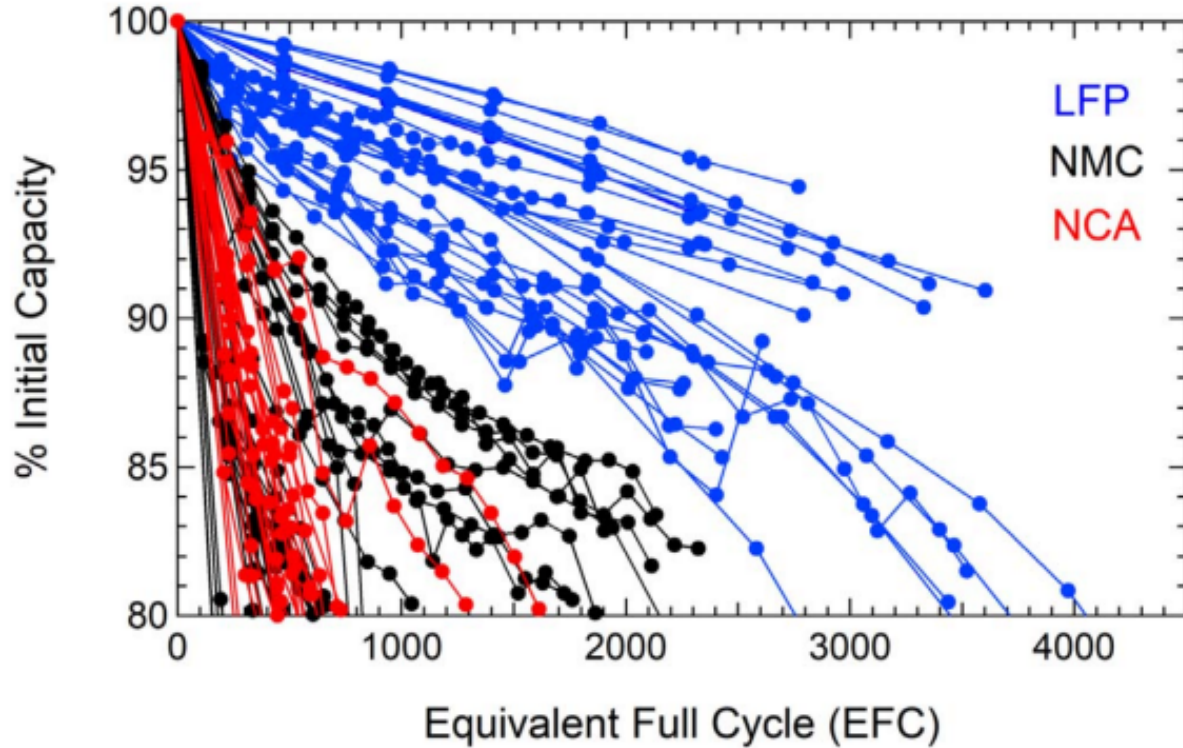
Reduced range

$$SOH_{Resistance} = \frac{\text{Current resistance } (\Omega)}{\text{Initial resistance } (\Omega)}$$

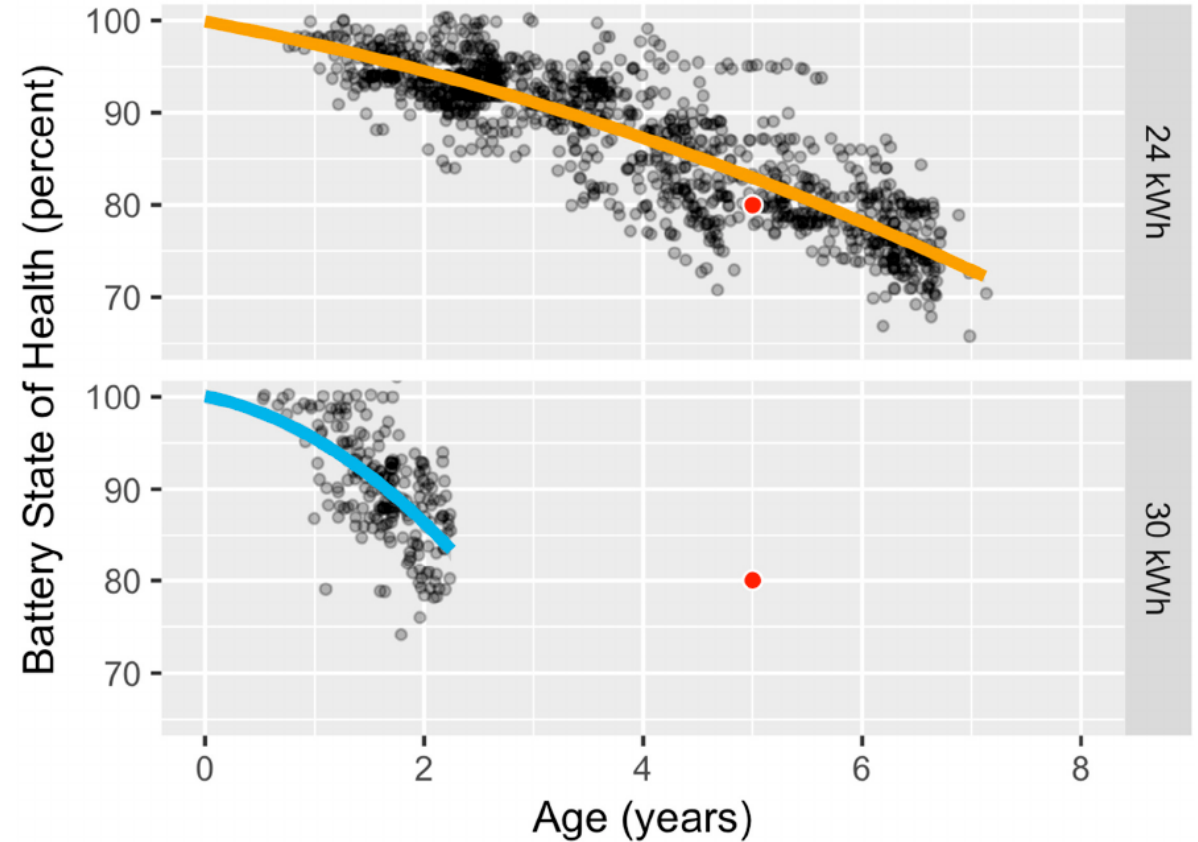
Reduced acceleration



# So how long do batteries last?



Lifetime of cells cycled under lab conditions

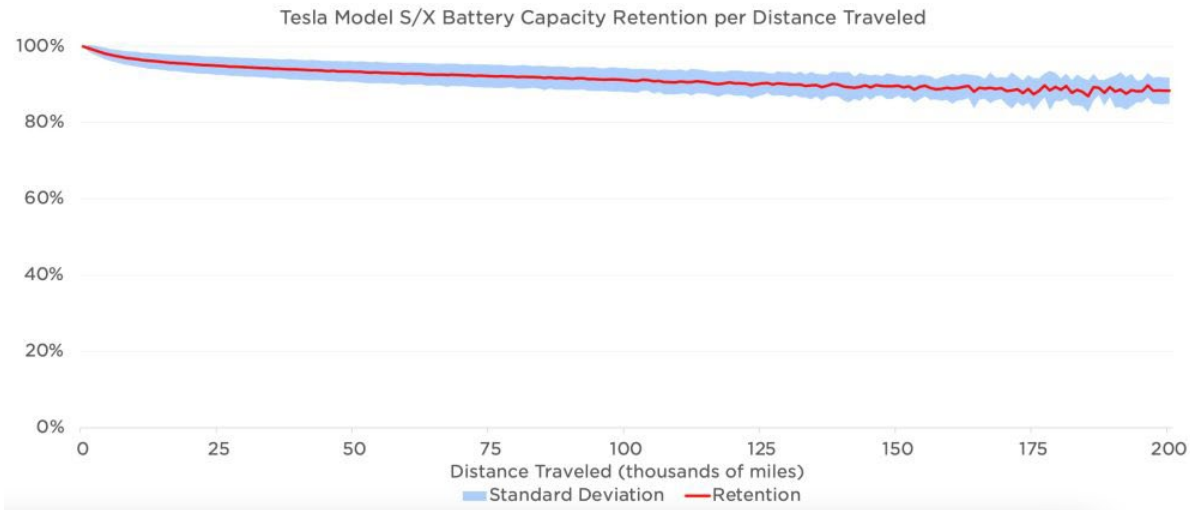


Nissan leaf manufactured between 2011-2017

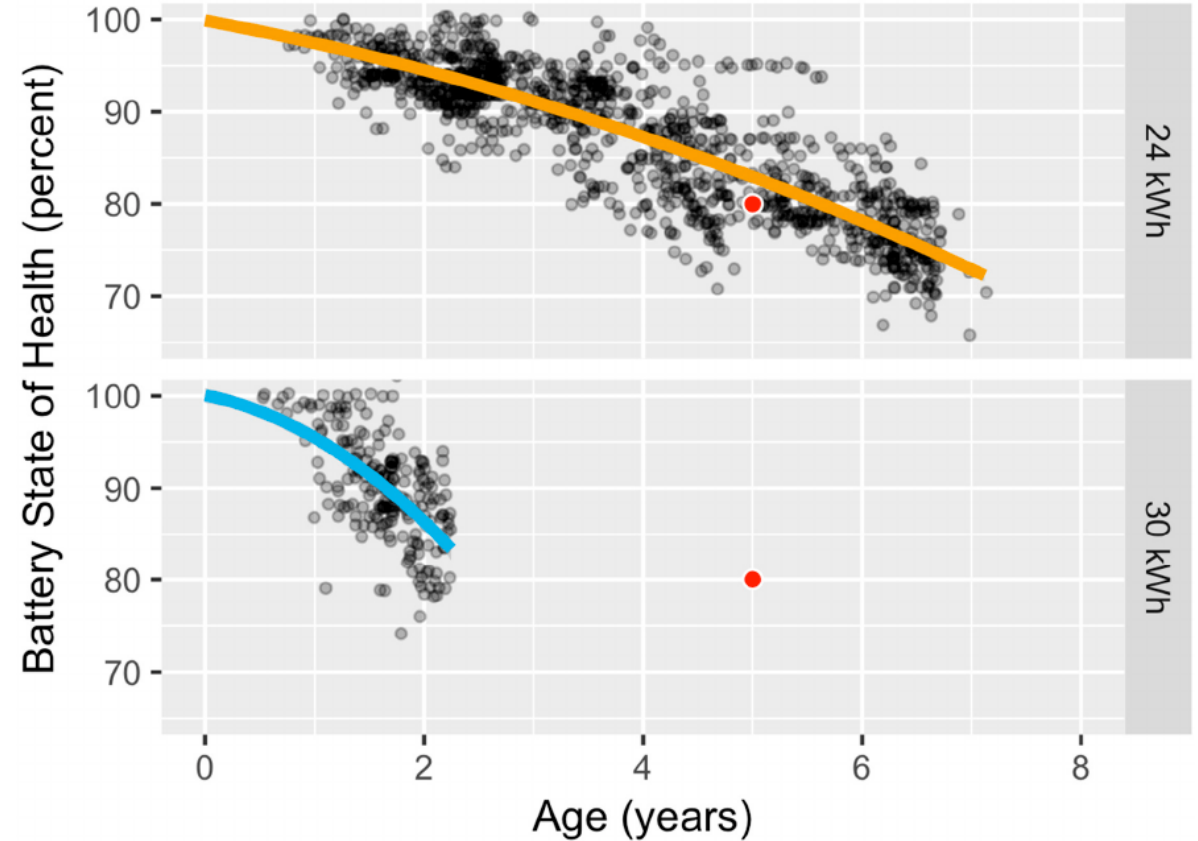


# So how long do batteries last?

It depends!



Tesla model S/X



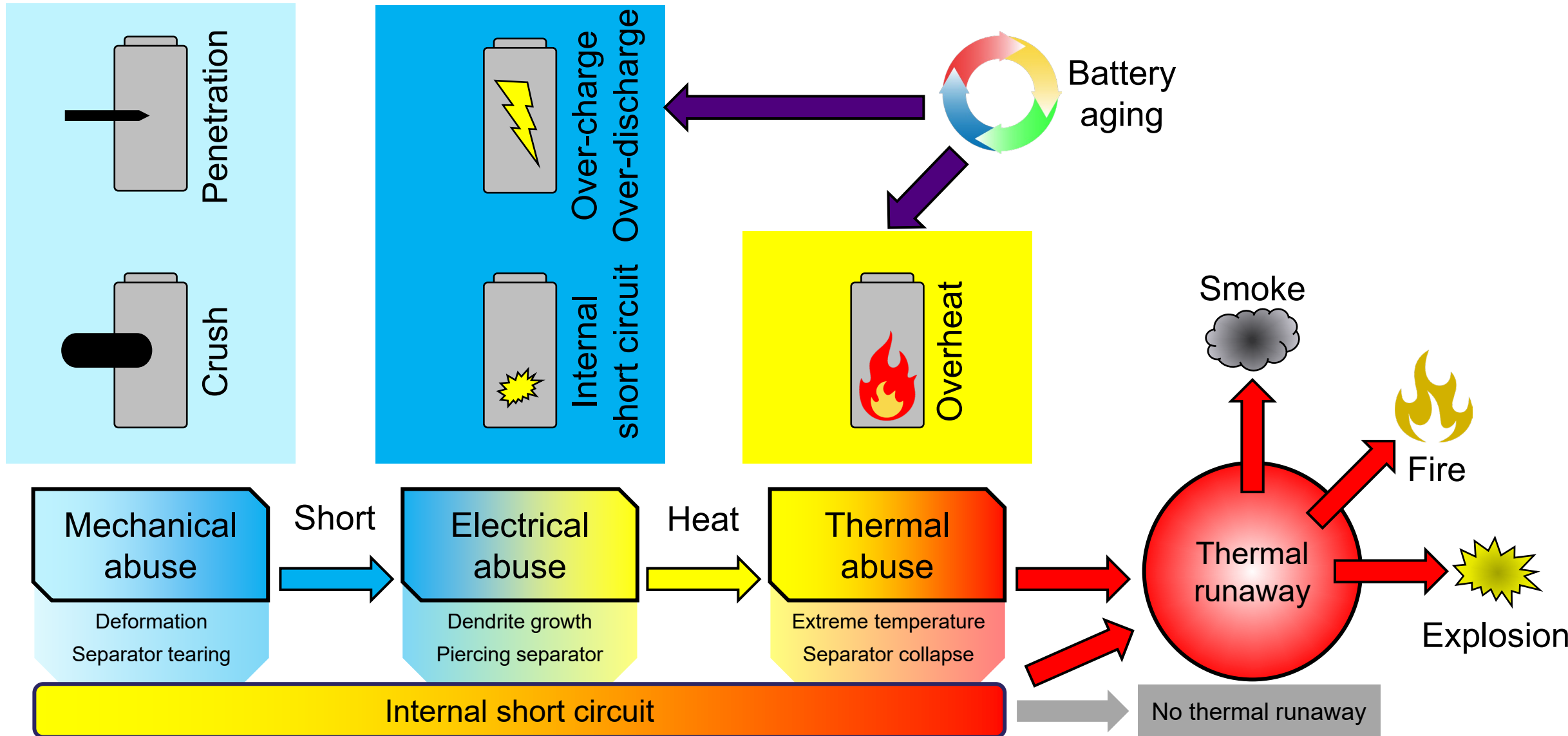
Nissan leaf manufactured between 2011-2017

# Failure of a lithium-ion battery due to thermal exposure

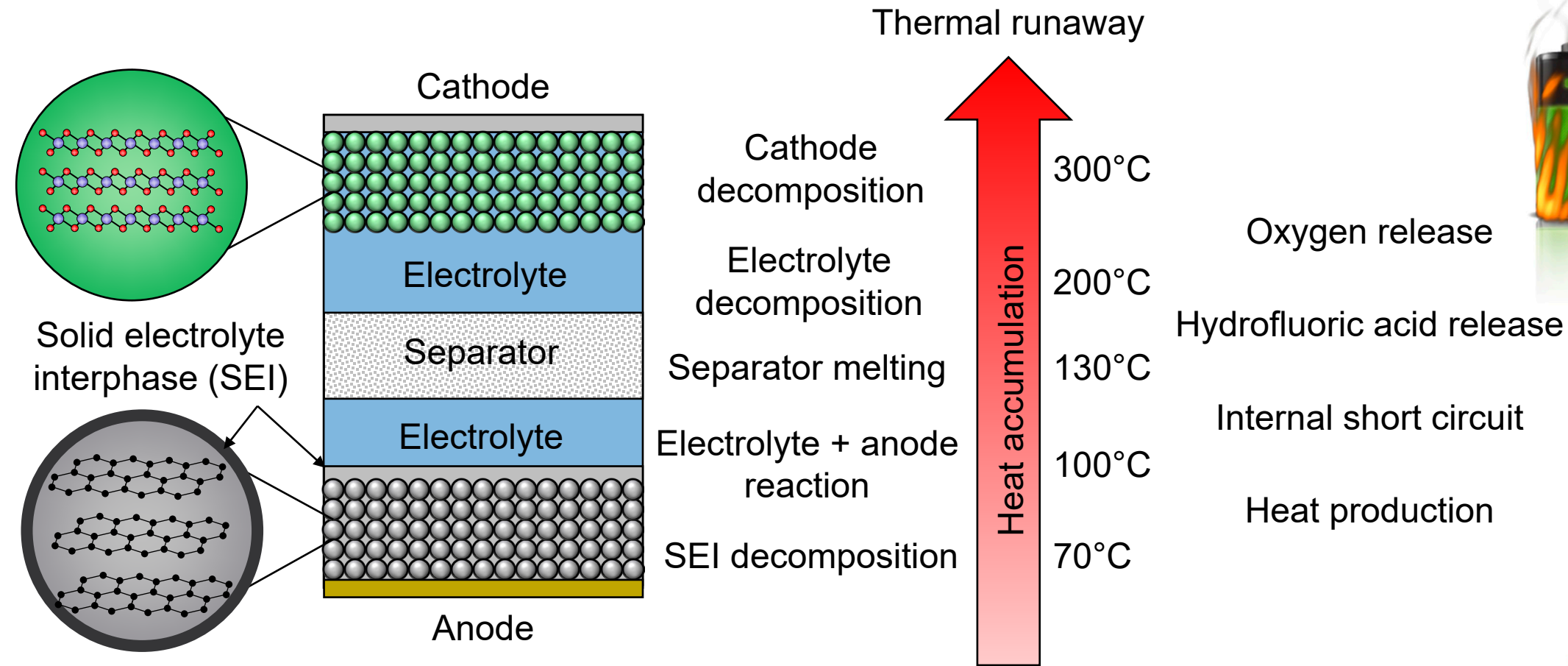


release  
of electrolyte

# Types of battery abuse



# What happens when lithium-ion batteries go wrong?



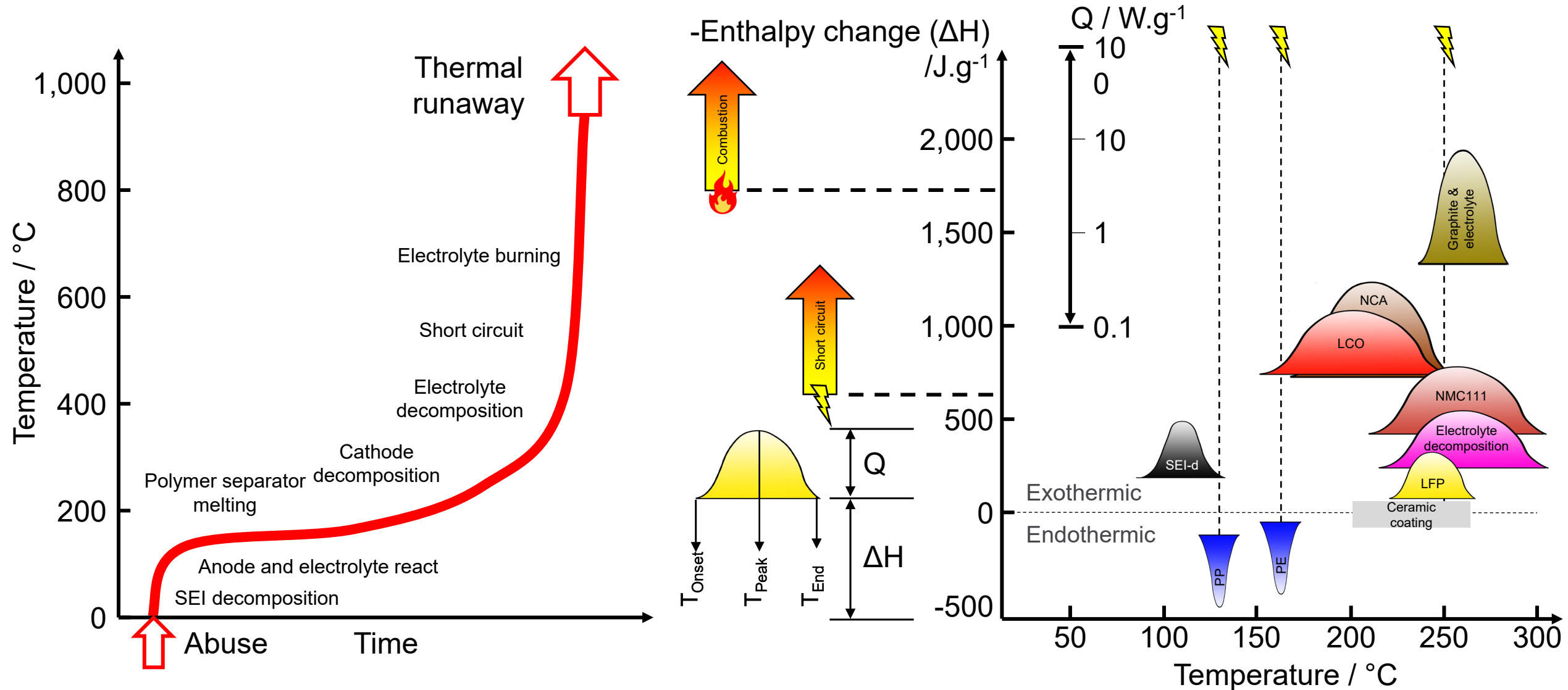
Common battery electrolyte components = Salt + solvent  
 Salt = Lithium Hexafluorophosphate ( $\text{LiPF}_6$ )  
 Solvent = Ethylene Carbonate (EC), Dimethyl Carbonate (DMC)



Adapted from Progress of enhancing the safety of lithium ion battery from the electrolyte aspect. Wang et al. Nano Energy 2018; 55 :93–114 .  
<https://www.evaluationengineering.com/applications/product-safety/article/13007366/fire-protection-engineers-address-liion-safety>  
<https://www.highspeedtraining.co.uk/hub/fire-triangle-tetrahedron-combustion/>



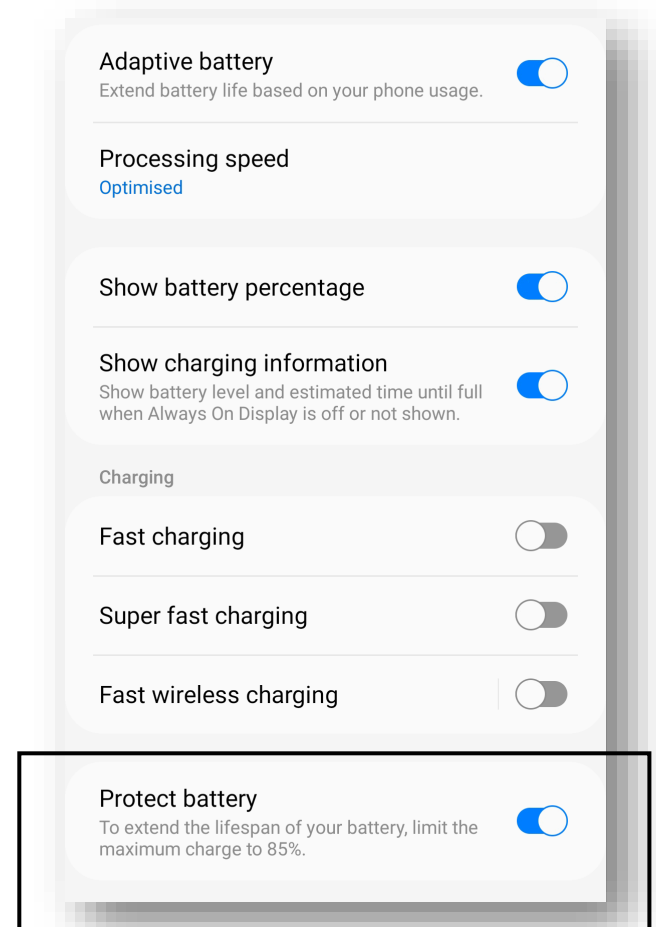
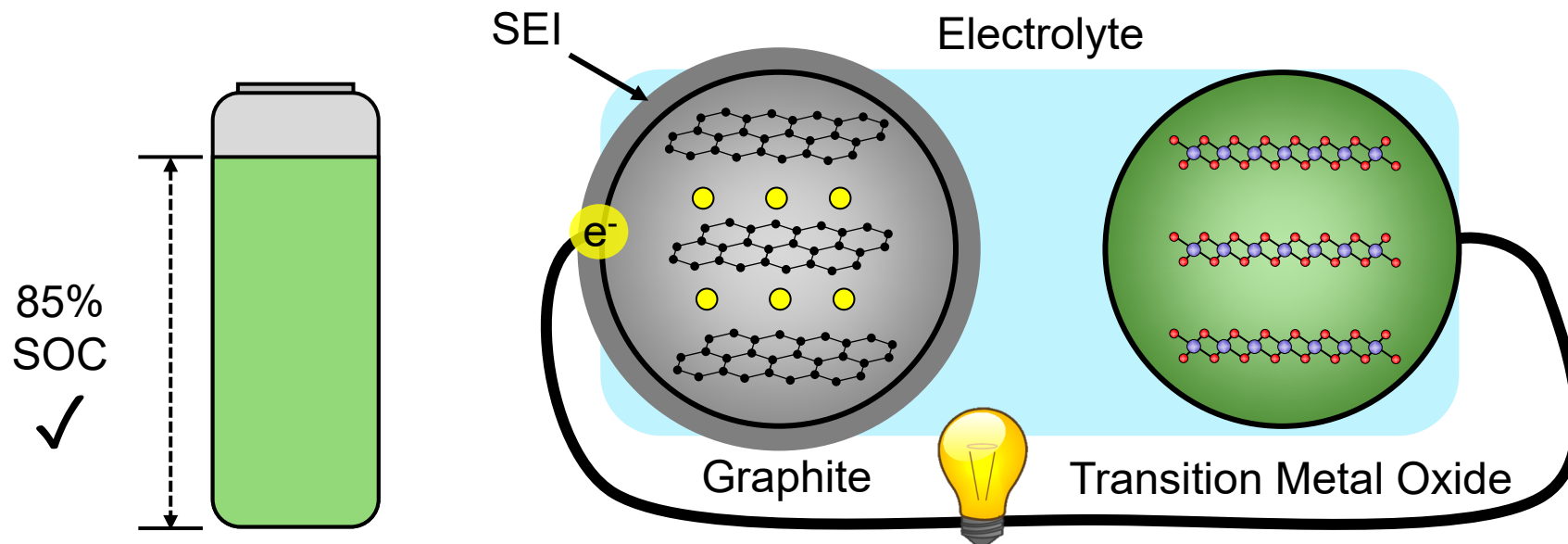
# Energy release during thermal runaway



# Reduce time at high state-of-charge

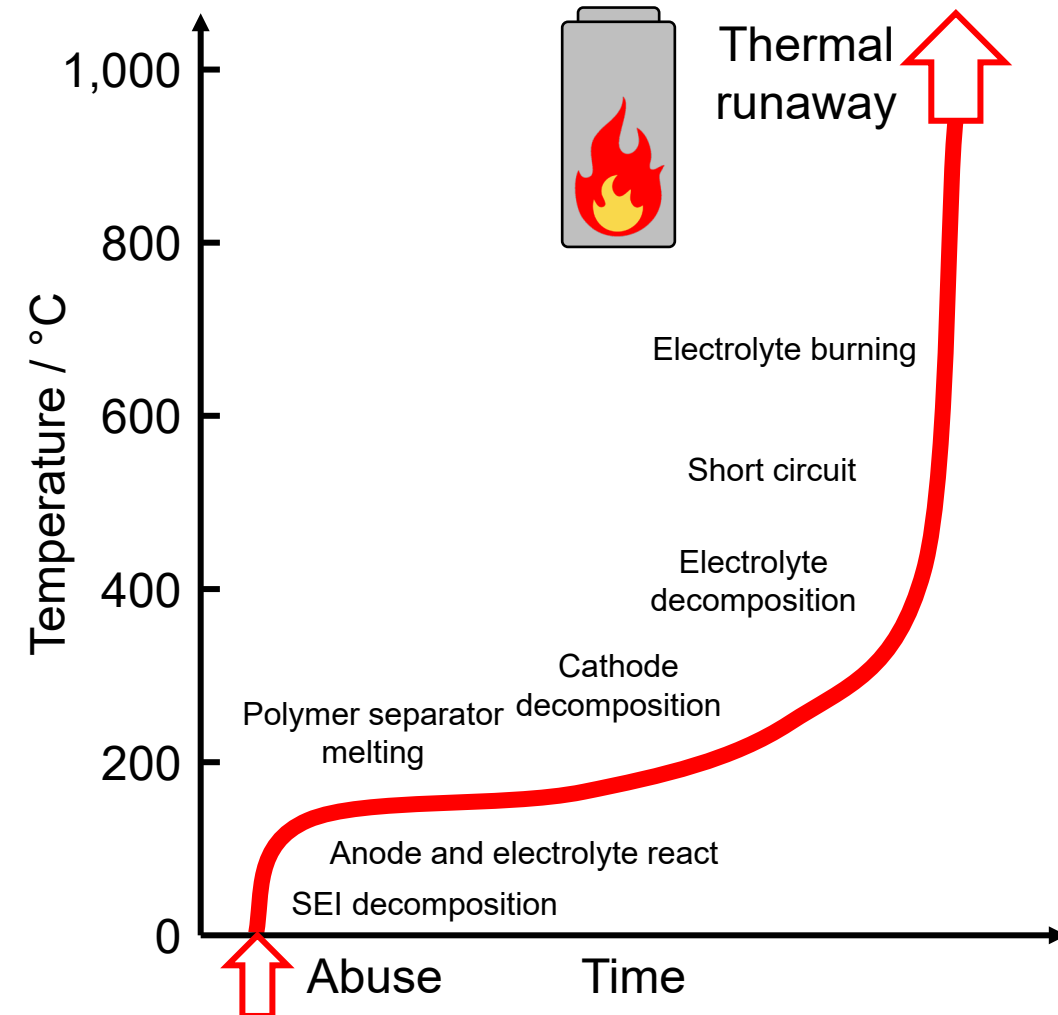
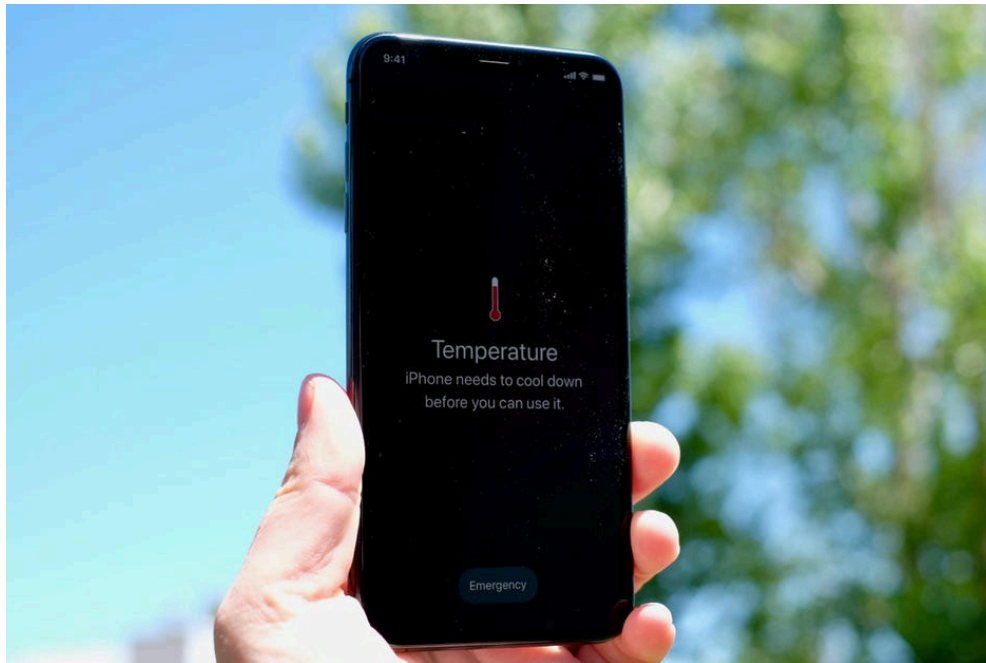
Keeping the battery fully charged can accelerate degradation

- ~85% state-of-charge is the optimum between energy and lifetime
- High state-of-charge accelerates the growth of the solid-electrolyte interphase (SEI) layer
  - Consumes lithium-ions = lower capacity
  - Thicker layer = high resistance/lower power



# Don't let the battery get too hot

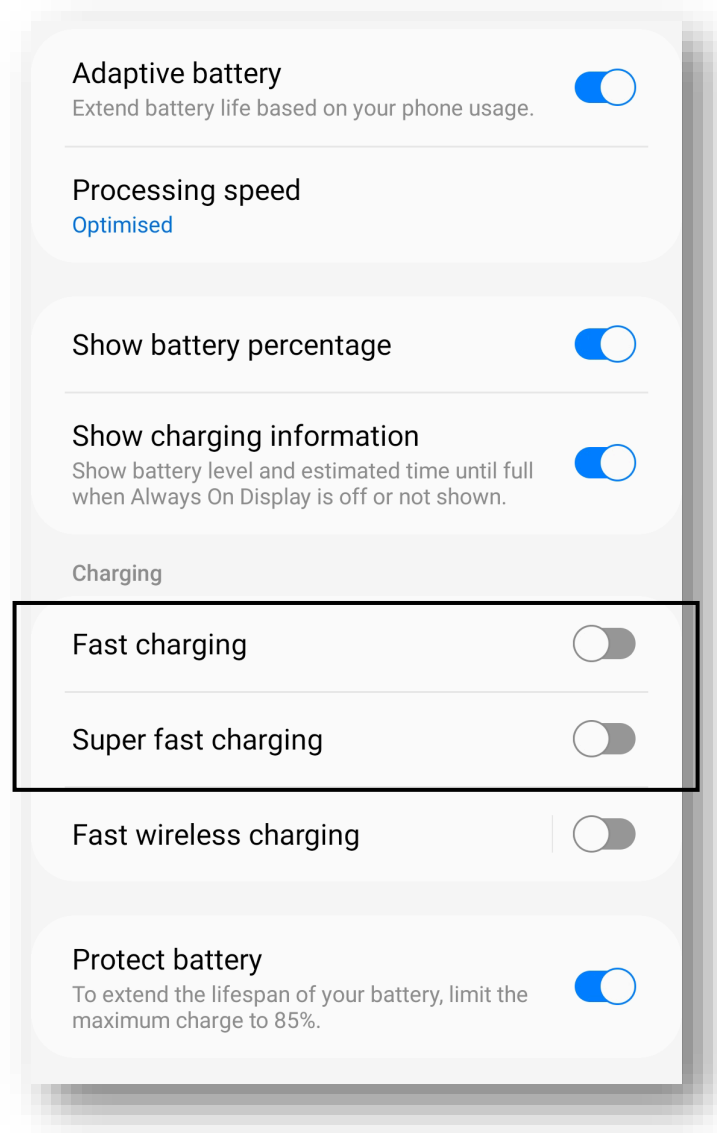
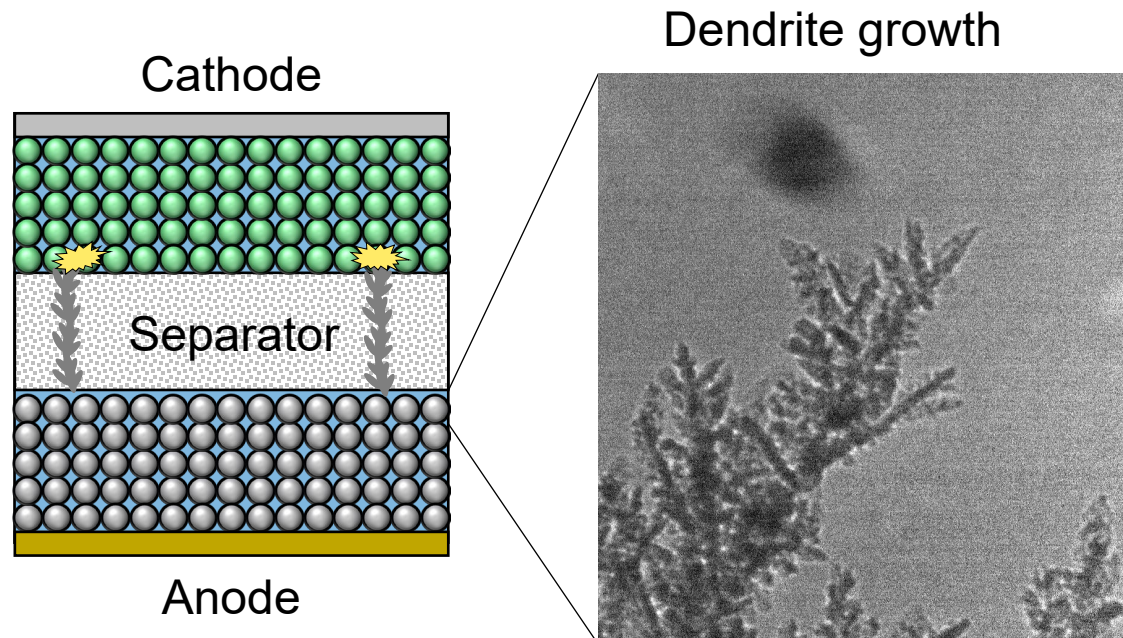
- At  $>70$  °C the battery can enter into thermal runaway
- Warm conditions accelerate the growth of the SEI
  - Decreases capacity and power
- Avoid putting batteries in hot locations





# Use slow charging

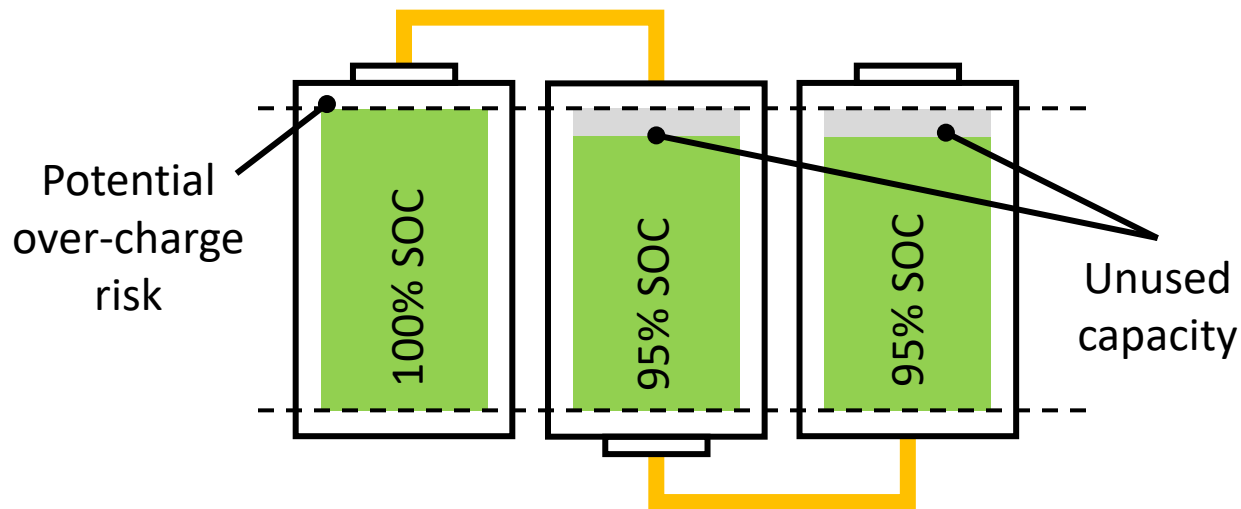
- Fast charging generally degrades your battery
  - Worse at low temperatures
- Fast charging can cause lithium dendrite formation
  - Leads to capacity fade
  - Potentially can cause an internal short-circuit and fire



# Avoid over-charge and over-discharge

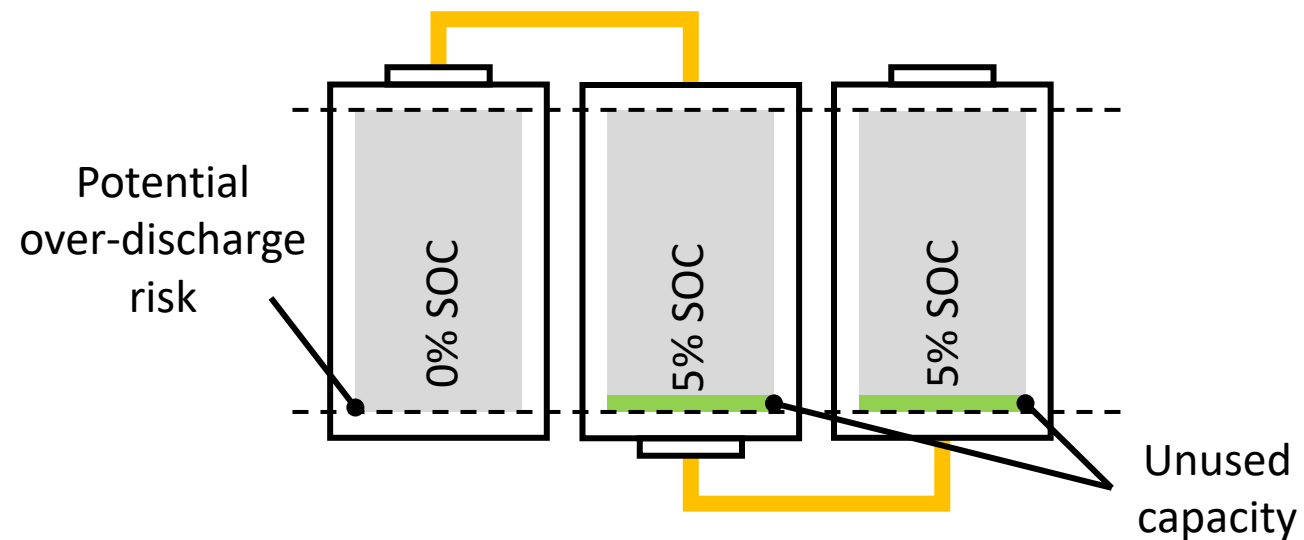
## Over-charge

- Most lithium-ion batteries have a maximum voltage of 4.2 V
  - Lithium iron phosphate batteries generally are fully charged at 3.6 V
- Overcharging can decompose the electrolyte
  - Causes bulging of the cell
- Issue in battery packs with cells in series



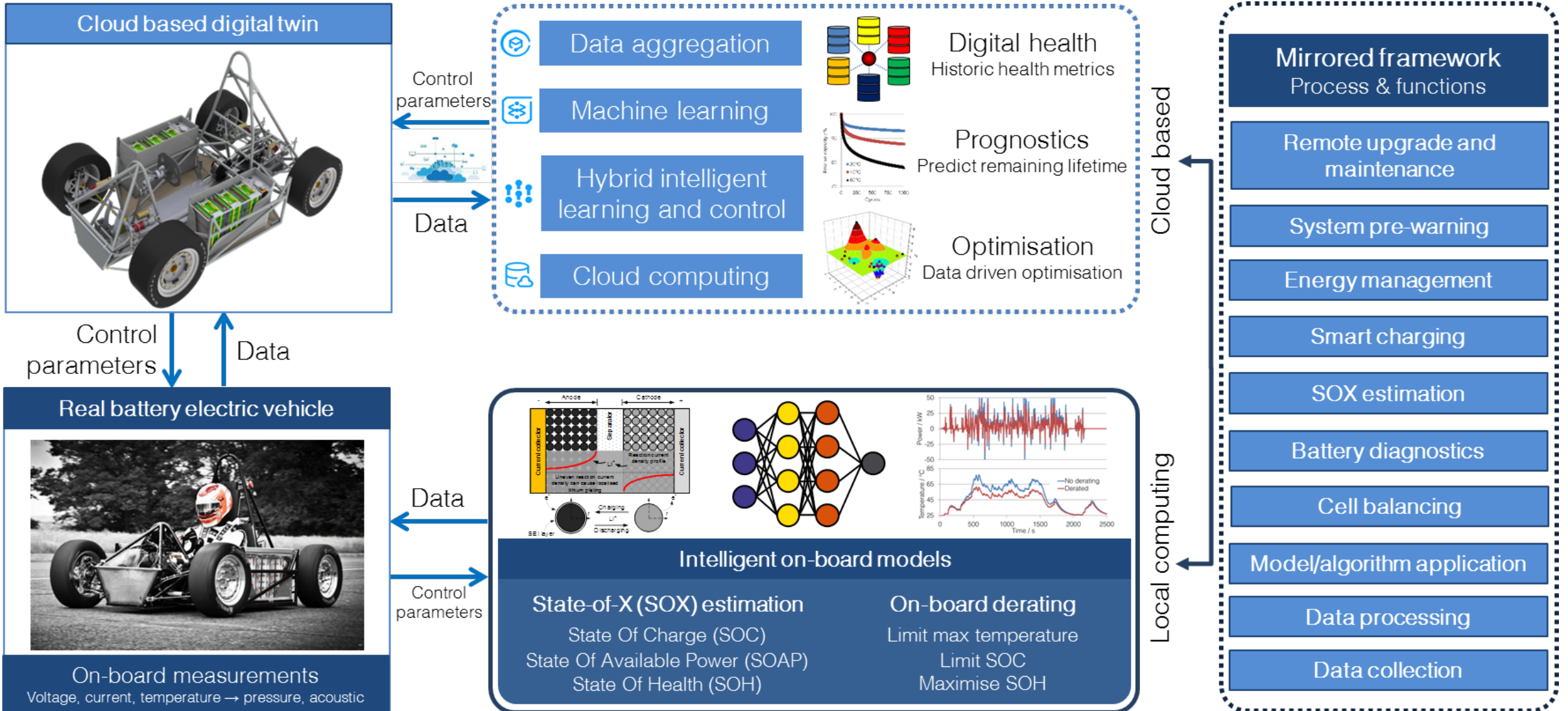
## Over-discharge

- Overdischarging the battery ( $\sim < 2.7$  V) can dissolve the copper current collector
- On next recharge, the copper can form copper dendrites and short circuits
- Problem in battery packs



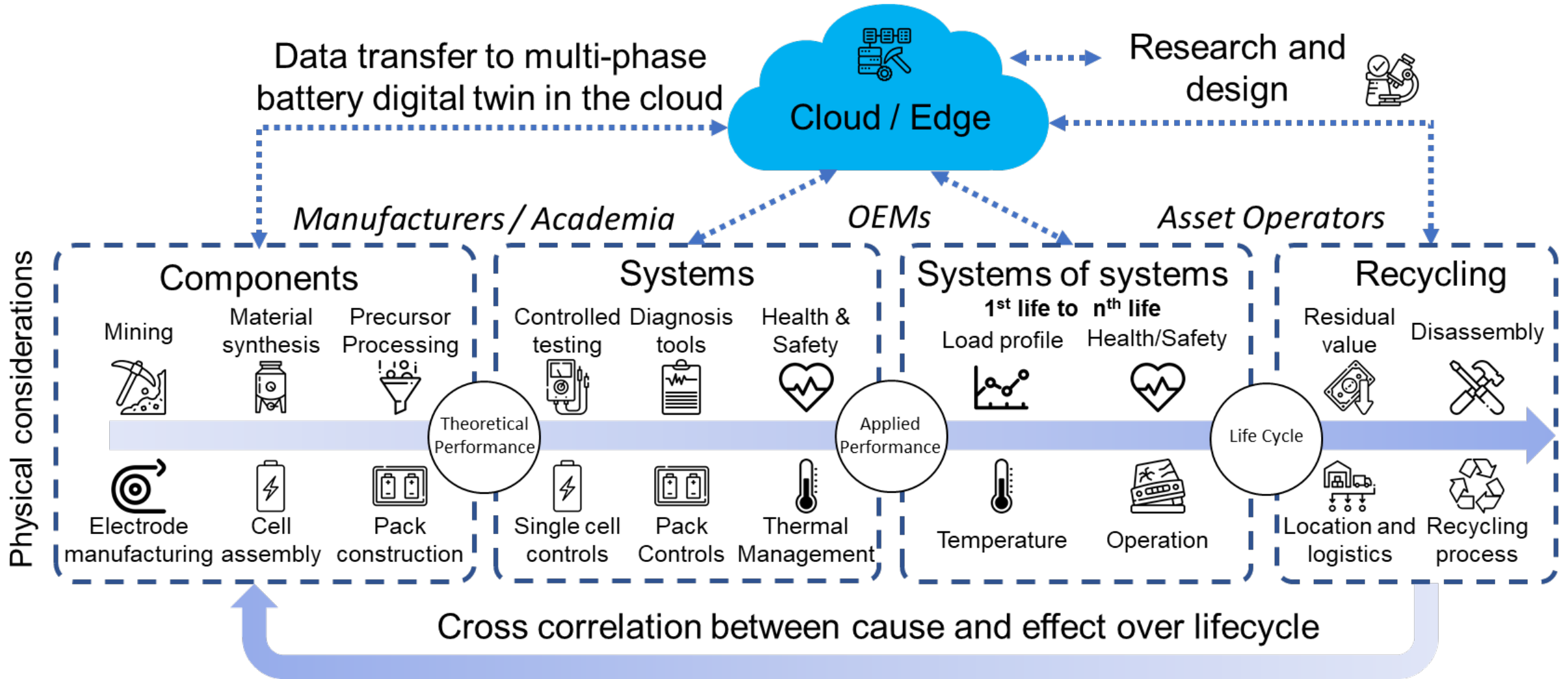
# Battery digital twins

Battery digital twins fuse real-time data with physically relevant models towards making asset specific decisions



# A holistic approach

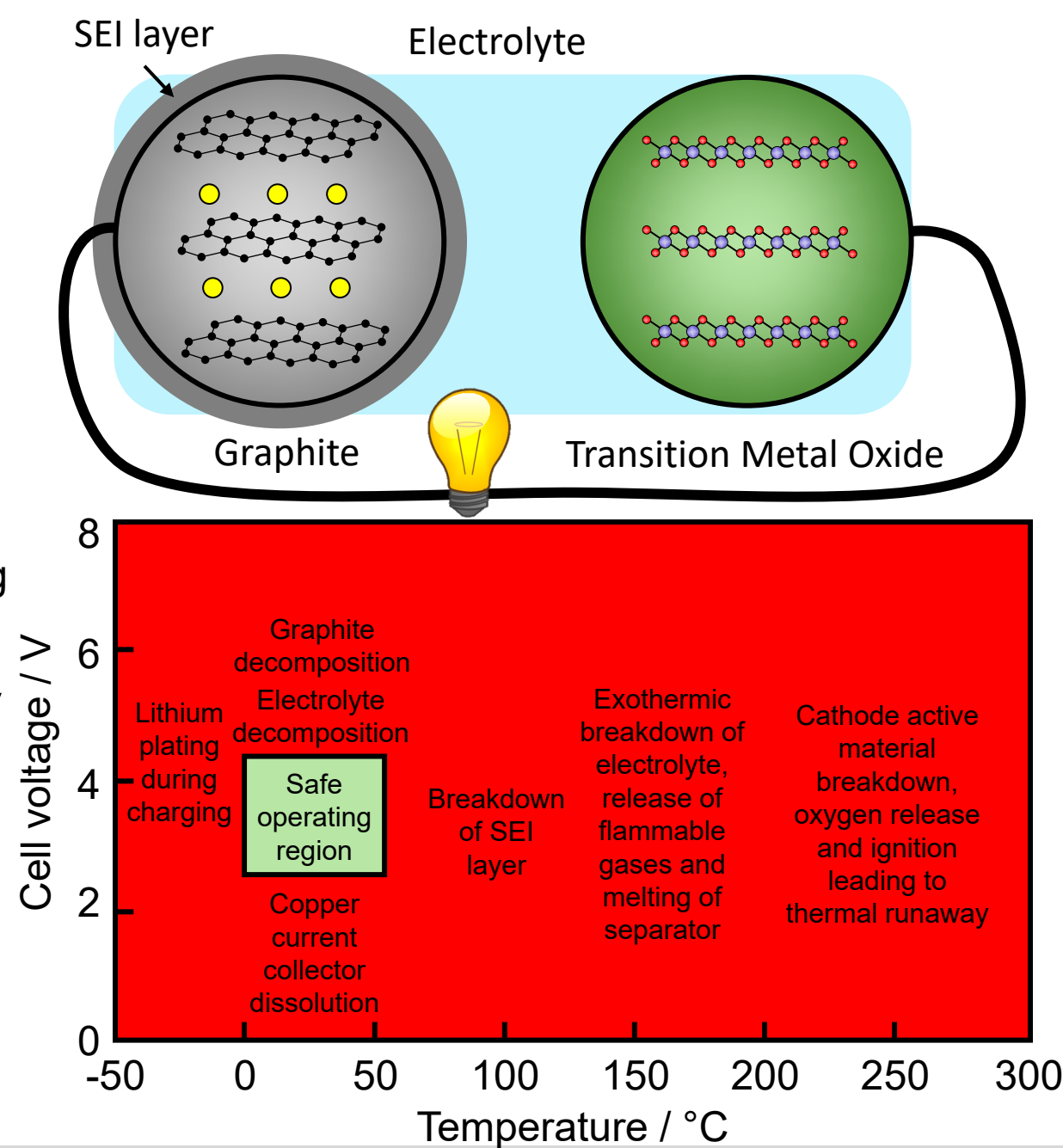
Battery digital twins can be a key enabler for battery passports





# Conclusions

- Electrification of transport is inevitable
- Different flavours of batteries
  - NMC/NCA = High performance, LFP = Low cost
- Many complex and coupled degradation modes
  - SEI layer growth @ High temperatures
  - Lithium plating @ Low temperature fast charging
  - Particle cracking @ High currents
- Thermal runaway of batteries can be caused by mechanical, electrical and thermal abuse
  - Likelihood of failure increases with battery age
- Some batteries safer than others
- Lifetime can be extended with careful use
- Battery digital twins can be an enabler







# Thank you for listening

[billy.wu@imperial.ac.uk](mailto:billy.wu@imperial.ac.uk) | Twitter - @ICBillyWu

Dyson School of  
Design Engineering



# Panel: Battery Degradation



Marc Palmer  
Autotrader



Scott Raffan  
Geotab



Dr Matt Stock  
Innovate UK



Gavin White  
About: Energy





# BVRLA Battery Health: Supercharge your knowledge

Scott Raffan - Solutions Engineering, Geotab

16th May 2023



# Global Footprint

A world map with a dark blue background and white outlines of continents. Numerous white circles with blue outlines are scattered across the map, representing global locations. The circles are most densely clustered in North America and Europe, with several others in South America, Africa, Asia, and Australia.

2177 employees worldwide

>45% of employees are STEM

42K+ customers in 165 countries

More than 700 partner ecosystem

\$410M USD revenue (2021)

3.3M+ subs globally

60% of subs with fleets size 500+

# Our mission: driving to innovation



## Global Market Leader

Center of the connected fleet industries providing best in class data for any vehicle and ecosystem to enable customers.



## Driving Innovation

Open platform enables innovation and fuels creativity enabling growth with. Empowering change. Never satisfied.



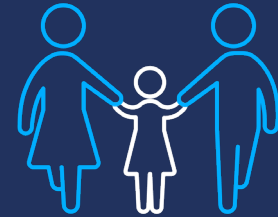
## Data Centric

Focused on data integrity used to solve different challenges for customers. Make better, real time decisions to deliver business impact.



## Sustainability

Helping organizations and communities drive to sustainable practices. Living it in our corporate environment. Committed to climate pledge. Leader in electrification with 236 models supported.



## Enabling Communities

Positively impacting where we live from safety, sustainability and productivity; it's beyond just vehicles. Everyone is a stakeholder.

# Why Geotab for EV?

## World's largest EV performance dataset in the world

### Trusted EV authority with unique benchmarking tools for EV performance

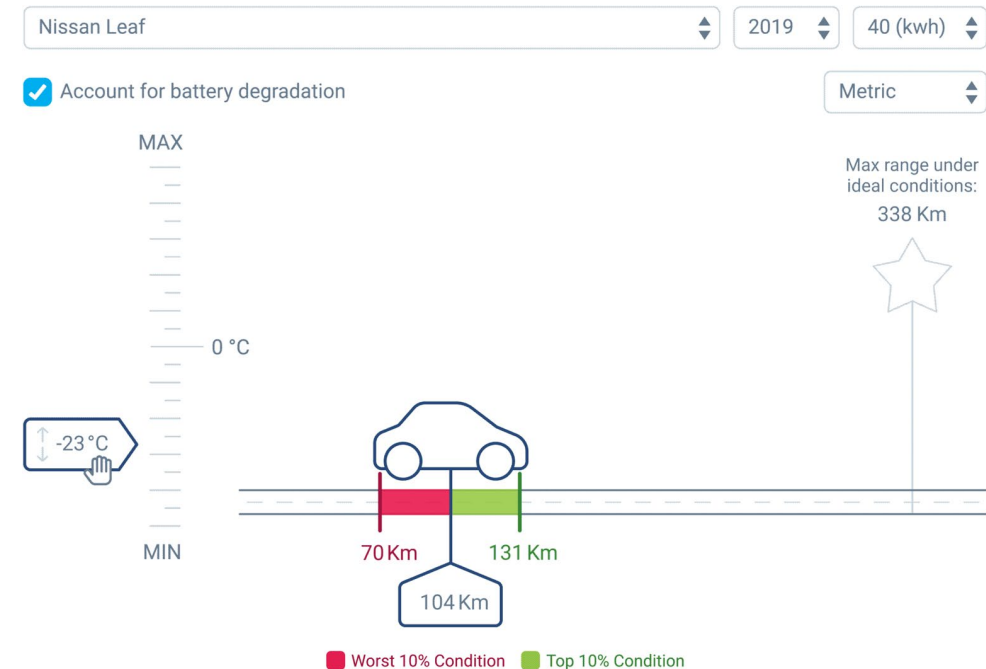
When adding EVs to your fleet, Geotab helps you understand key performance metrics for battery degradation and range implications. Our tools are built based on real-world EV trip data from over 6,000 EVs and represent 1.8 million days of data.

Gain an understanding of:

- Do EV batteries wear out like other standard technology?
- Does how I use and charge my vehicle affect its battery life?
- How does temperature affect my vehicle's range?

[View our EV battery degradation tool](#)

[View our EV temperature range tool](#)



## We wanted to know:

### How have EV batteries fared in the real world?

- Should EV drivers be concerned?
- Is it different across different MMYs?
- What external factors impact degradation rates? Is there any correlation with:
  - Usage
  - Hot/Cold climates
  - Charging type - L1, L2, DCFC
- What can an EV operator do to limit degradation?

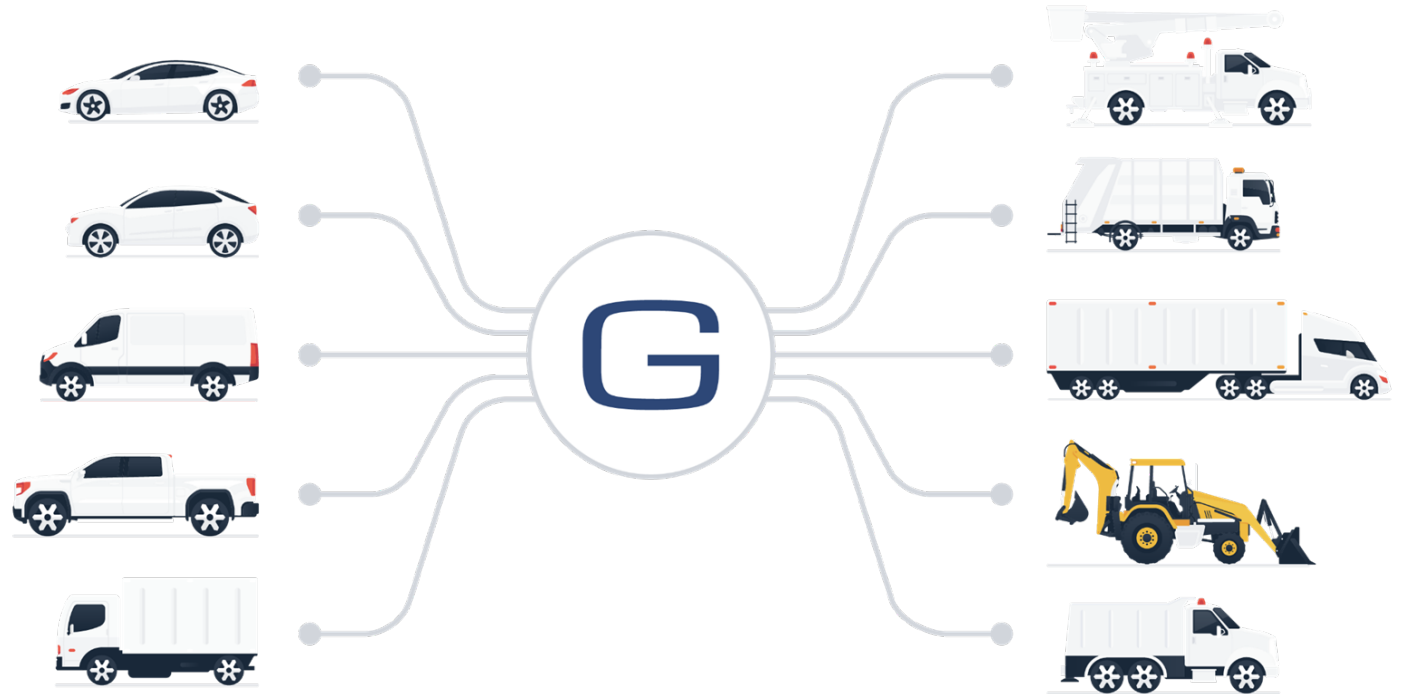




# The Results

Over 3 million trips analysed, with over 6000 EVs. Full analysis to be published soon

- Average degradation was observed to now be **lower** than initial studies
  - Sub 2% per year
- High use and charge cycles are not the main factor of degradation
- Charge management is key
  - Avoid DCFC in hot scenarios
  - Minimise time that batteries at sat with 100% SOC
- Adopt a “right size” approach to selecting your EV
  - Give a buffer on required range and actual range



# Let's stay connected

f  in   | @geota  
b

GEOTAB<sup>®</sup>



# Sharing insights about battery degradation and how battery development/innovation will change this

16<sup>th</sup> May 2023



# Battery degradation



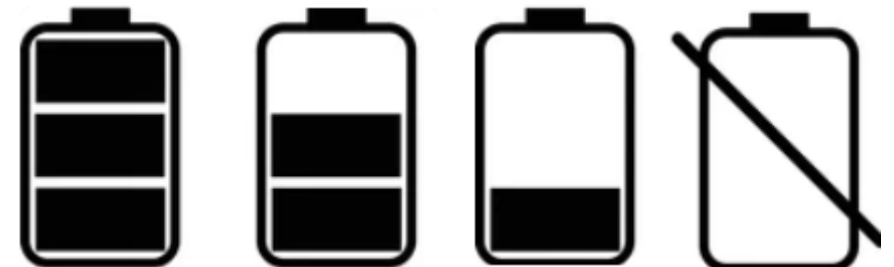
## Problem:

Loss of active lithium, and increased internal resistance

## Factors:

1. Temperature
2. Depth of discharge
3. Charging rates
4. Battery cell design
5. Age

How can innovation in battery technology help?





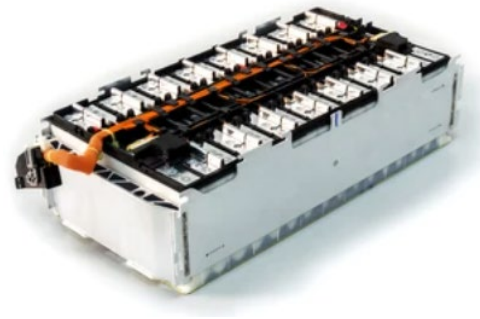
# Innovations in battery technology



**Cell**



**Module**



**Pack**



**Vehicle**



# Innovations in battery technology



## Cell



## Module



## Pack



## Vehicle



- Materials
- Electrolytes
- Mechanical optimisation
- Manufacturing methods

# Innovations in battery technology



## Cell



- Materials
- Electrolytes
- Mechanical optimisation
- Manufacturing methods



## Module



- Module design
- Thermal management
- Cell connections
- Monitoring and control



## Pack



## Vehicle



# Innovations in battery technology



## Cell



- Materials
- Electrolytes
- Mechanical optimisation
- Manufacturing methods



## Module



- Module design
- Thermal management
- Cell connections
- Monitoring and control



## Pack



- Pack integration
- Thermal management
- Structural design
- Monitoring and control



## Vehicle





# Innovations in battery technology



## Cell



- Materials
- Electrolytes
- Mechanical optimisation
- Manufacturing methods



## Module



- Module design
- Thermal management
- Cell connections
- Monitoring and control



## Pack



- Pack integration
- Thermal management
- Structural design
- Monitoring and control



## Vehicle

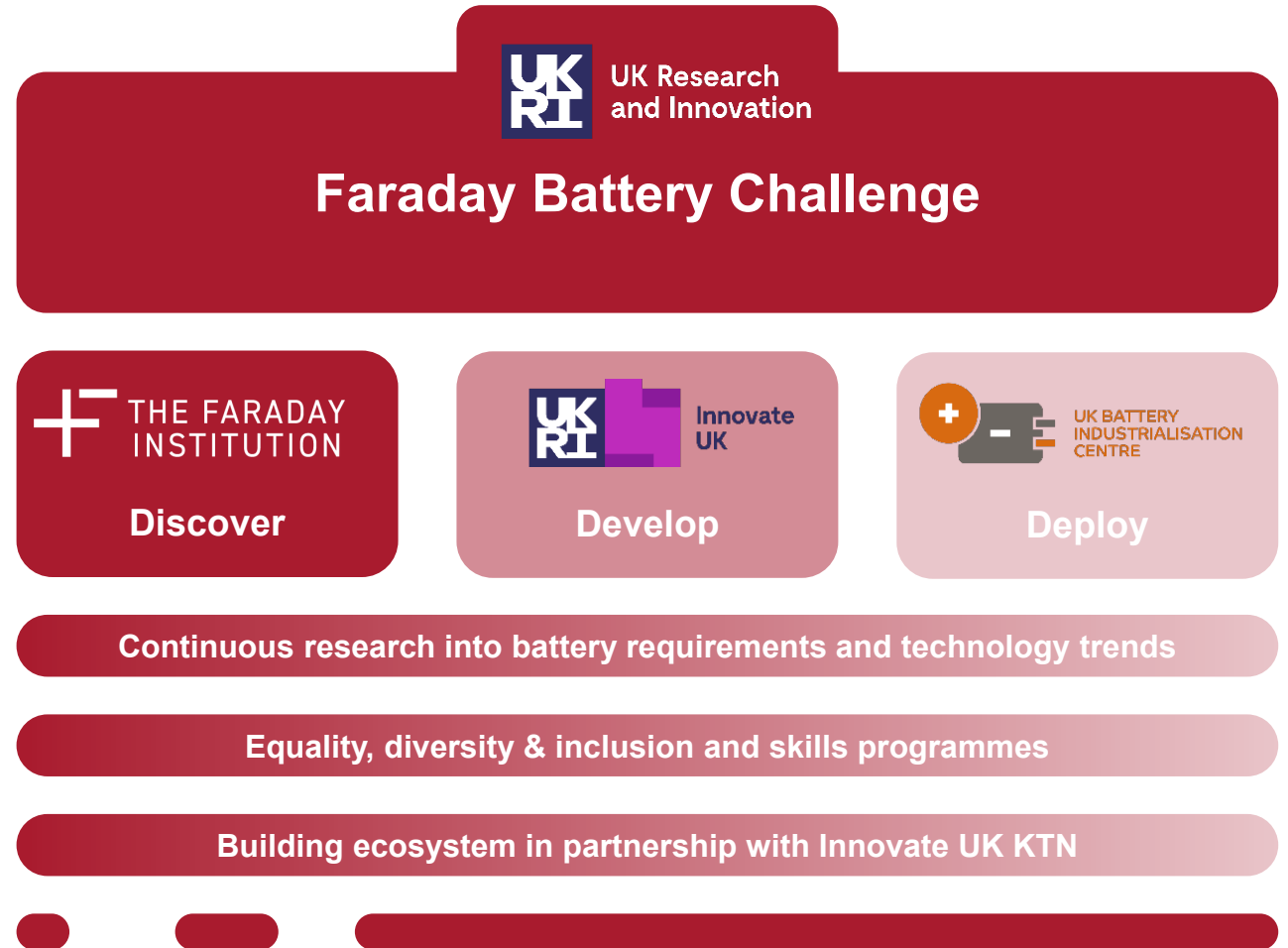


- Vehicle-to-grid
- Charging methods
- Energy management

# What is the Faraday Battery Challenge?



- £541 million programme
- Running from 2017 to 2025
- Part of the UKRI Challenge Fund
- Delivered by Innovate UK



# What is the Faraday Battery Challenge?



### Extending battery life

Understanding the mechanisms of degradation of lithium-ion batteries.

### SOLBAT – all-solid-state lithium-metal anode batteries

Addressing fundamental research challenges facing the realisation of solid-state batteries in automotive applications.

Grant contribution: £21,800,000

### LISTAR – the lithium-sulfur technology accelerator

Developing commercially relevant lithium-sulfur batteries that surpass the capabilities of existing Li-ion technology.

Grant contribution: £12,900,000

### Executive summary

There is a need to develop batteries which surpass the practical capabilities of lithium-ion batteries to enable the identification of applications including aerospace and heavier electric vehicles. While there are several realistic candidates, the Li-S chemistry combines relative technical maturity with a practical limit that places the technology in a unique position to facilitate commercialisation.

Compared with conventional Li-ion batteries, Li-S cells store more energy per unit weight and can operate in a wider operating temperature range. They may also offer safety and cost improvements. Yet the widespread use of Li-S faces major hurdles that stem from sulfur's insulating nature, migration of discharge products leading to the loss of active material, and degradation of the metallic lithium anode. Scientists and engineers need to know more about how the system performs and degrades in order to overcome current limitations in the power density and lifespan of Li-S cells that could unlock their use and see their transition from research into prototype and industry.

LISTAR is designed to address these challenges. The consortium is generating new knowledge, materials and engineering solutions, thanks to its application guided approach, which dual focus on fundamental research at material and cell level, and an improved approach to system engineering. The project is addressing the key areas of research: cathodes and cathode electrolytes and electrochemistry, anodes and new cell concepts, cell and system engineering, and Li-S characterization. In doing so, the consortium is seeking to enable rapid improvements in Li-S technologies, with the aim of securing the UK as the global hub for the research, development and commercialisation of this emerging technology.

**March 2025**

- Demonstrate a battery management system to maximise performance
- Develop bespoke advanced cell monitoring and diagnostic techniques from the subset of the chemistry's commercialisation
- In doing so, the project aims to pave the way for multiple Li-S cell concepts: an 'energy' and 'lifetime' cell, with significantly improved operating temperature window, power and energy densities, and cycle life.

**Partners**

- University of Oxford (Lead)
- Newcastle University
- Diamond Light Source
- 3 Industry Partners

[www.solbat-faraday.org](http://www.solbat-faraday.org)

### Project innovations

LISTAR is tracking the technical requirements for Li-S batteries in strategic markets with near-term opportunities such as aerospace applications. The project anticipates that the first viable commercial products will be for niche markets that place a premium on energy density, which will subsequently stimulate others (including automotive). Alongside the research partners, the consortium's industry partners have the capability to fast-track research to higher technology readiness levels and efficiently provide proof-of-concept manufacture of the new developments.

**Partners**

- University College London (Lead)
- University of Cambridge
- Coventry University
- Cardiff University
- University of Birmingham
- Imperial College London
- University of Nottingham
- University of Oxford
- University of Southampton
- National Physical Laboratory
- Amosco Technology Institute
- 3 Industry Partners

**Contact:** Professor Paul Stalling, Email: p.stalling@ucl.ac.uk, Web: www.listar.ac.uk

### NEXGENNA – sodium-ion batteries

Improving the energy storage, power and lifetime of sodium-ion batteries while maintaining sustainability, safety and cost advantages

Grant contribution: £13,900,000

### Executive summary

NEXGENNA will develop the NEXT Generation of Na-ion batteries. Its mission is to surpass Li-P graphyne by improving the energy storage, power, and lifetime of sodium-ion while maintaining sustainability, safety, and cost advantages.

Sodium-ion batteries (NIBs) are an emerging battery technology on the cusp of commercialisation, with promising cost, safety, sustainability and performance benefits when compared to lithium-ion batteries. They use widely available and inexpensive raw materials and avoid lithium ion production methods, ensuring rapid scalability. NIBs will also fulfil the need for low-cost electro-transport options in the densely populated and polluted concentrations of developing economies.

NEXGENNA is taking a multi-disciplinary approach incorporating fundamental chemistry through scale-up and cell manufacturing. Many models of future renewable networks encompass storage for increased network resilience and to ensure the efficiency of small-scale renewable sources and the widespread use of commercial NIBs that this project will facilitate, would aid the realisation of these models, and aid the need for low-cost electro-transport options in the densely populated and polluted concentrations of developing economies.

**Timeline with milestone/deliverables (September 2025)**

- Discover and develop next generation electrode materials, giving higher sodium mobility and therefore higher power
- Develop the understanding of interface formation and cell degradation to extend cycle life
- Optimise key industry-relevant materials for scale-up
- Demonstrate nascent NEXGENNA technology in pouch cells
- Improve the industrial state-of-the-art by delivering a novel medium power, low-cost sustainable or energy pouch cell design.

**Partners**

- University of St Andrews (Lead)
- Imperial College London
- University of Cambridge
- Imperial College London
- Lancaster University
- University of Birmingham
- ISIS Neutron and Muon Source (STFC)
- 3 Industry Partners

**Contact:** Professor John F B Stone, Email: jfb@st-and.ac.uk, Web: www.nexgenna.org

### Project innovations

The project benefits from strong academic-industrial links across the value chain. Industry partners bring strengths in terms of materials, cell fabrication and electrode manufacturing. By working closely with these partners, the project team will ensure that it meets explicit and successfully deploys cutting-edge expertise, making the UK a leader in this technology for stationary and low-cost batteries for transportation applications.

**Partners**

- University of St Andrews (Lead)
- Imperial College London
- University of Cambridge
- Imperial College London
- Lancaster University
- University of Birmingham
- ISIS Neutron and Muon Source (STFC)
- 3 Industry Partners

### FutureCat – high nickel content, high performance cathode materials

Grant contribution: £13,400,000

### Multiscale modelling

Bringing together a multidisciplinary team to develop fast, highly accurate models to speed up battery development and ensure safe operation for longer battery life.

Grant contribution: £22,900,000

### Executive summary

Internationally recognised experts are using experimental techniques for the behaviour of the atomic-scale continuum. Fast, accurate models, incorporating physics and advanced mathematical techniques, are being developed to be directly usable for digital twinning of whole cells and packs. This will parameterise higher level models, such as the complex interactions between electrode interface, rapid reformation methods are being developed, time and cost of customising models for the user.

Understand the physicochemical mechanisms of graphite and anode free electrode cathodes is being placed on the interaction, effects of positive electrode materials on coppering these pathways of the electrode interface.

Developing fast, highly accurate models to speed up battery development and ensure safe operation for longer battery life.

**Partners**

- University of Sheffield (Lead)
- University of Cambridge
- Lancaster University
- University of Warwick
- Imperial College London
- University of Nottingham
- University of Birmingham
- Diamond Light Source
- ISIS Neutron and Muon Source
- 4 Industry Partners

<http://futurecat.ac.uk>

### Project innovations

FutureCat is targeting represent significant research opportunities. FutureCat, in collaboration with University of Warwick, is well positioned to develop solutions for next-generation cathode materials relevant battery formats such as pouch cells. The is joined by industry partners across the battery chain. Three new partners join the consortium in working on material lifetime extension via atomic twinning, new advanced electrolytes to maximise performance, and advanced X-ray tomography reformation methods to make made batteries as they are needed.

**Partners**

- University of Sheffield (Lead)
- University of Cambridge
- Lancaster University
- University of Warwick
- Imperial College London
- University of Nottingham
- University of Birmingham
- Diamond Light Source
- ISIS Neutron and Muon Source
- 4 Industry Partners

[www.ukri.org/publications/faraday-battery-challenge-funded-projects/](http://www.ukri.org/publications/faraday-battery-challenge-funded-projects/)

# What is the Faraday Battery Challenge?



### IMPACT – IMPROVING BATTERY COOLING TECHNOLOGIES

This project produced new sensors to image the current flow within EV batteries. They have since been developed into a commercial battery analysis system by CDO2.

**Novel self-regulating CHIP (Cooling or Heating Integrated Pipe) for BTMS**

The major objective of this project is to improve the safety and efficiency of current EV batteries by the incorporation of smart self-regulating heating technology and optimised cooling.

**Project costs**  
Total project costs: £499,903  
Grant contribution: £342,424

**Executive summary**

This history study has demonstrated the utility of using Heat Trace aluminium/polymer heating technology in EV BTMS. The inherently temperature safe self-regulating heaters cannot overheat under their own power. Compared to traditional PTC, the direct application of heat heaters to the cells enables significant enhancements in efficiency. In tests, the energy required to raise the module temperature from -10 to 20°C reduced by up to 71%, and the time required reduced by 25%.

This exceptional heating performance is integrated with:

- Optimisation of laser welding process for electrical and fluid connectors complete - November 2020
- Heating and cooling specifications confirmed, design evaluations and CFD modelling - January 2020
- Optimal design selected and prototyping manufacturing feasibility established - March 2020
- Development and production of prototype heater elements complete - November 2020

**Partners**  
cdo<sup>2</sup>, inxex, Queen Mary, US, HEAT TRACE, WWMG

**Project innovations**

- The innovative features include:
  - The CHIP module can be operated either as a heating module or a cooling module
  - The inherently temperature safe polymer heater improves safety and minimises the risk of thermal runaway
  - The direct application of heat to the cells enables significant energy and time or power savings
  - The aluminium based design enables flexible geometry and mass reduction
  - Due to the direct application of heat to the cells, the thermal efficiency and heating rate is substantially improved
  - The use of high-precision laser welding for fluidic and electrical interfaces results in high reliability
  - The CHIP module can be customised to any cell type or battery pack configuration

**Contact:**  
Chris Jones Email: chris.jones@heat-trace.com Web: www.heat-trace.com

### CoRuBa

Next generation thermal interface materials to enhance cell life and enable rapid charging.

**BAFTA (Battery Advances for Future Transport Applications)**

The aim is to deliver a toolkit of software, models, and methodologies, implemented on an innovative BMS platform and validated to a statistically significant level.

**Battery management control system for Advanced Battery Engineering (BABE)**

Developing the technical and commercial stages of Brill Power's revolutionary Battery Management Control System in EV fleet applications.

**Project costs**  
Total project costs: £209,493  
Grant contribution: £129,980

**Executive summary**

Battery systems are one of the greatest challenges to EV uptake. According to Research & Markets (2019), average expected lifetime of EV batteries is only five years, after which the battery needs replacing. Considering that an EV battery can be around 40% of the vehicle cost, such replacements are financially infeasible.

The key achievements of this project were an assessment of E-Car EV battery health and the design, build and test of a new version of Brill Power's battery management system, value proposition testing with stakeholders in the EV market, a business plan for Brill Power for the EV market, a market and dissemination plan for Brill Power, and a technology strategy plan.

**Timeline with milestones and deliverables**

Project start date: 01 February 2018  
Project completion date: 31 March 2019

- Report with summary of current battery performance, warranties, costs and replacement options
- Collection of data on E-Car fleet performance
- Report / Conclusions from Data Analytics
- Building and testing of updated iteration of Brill Power Battery Management System (BMS)
- Application of findings to develop value proposition
- Summary of value proposition testing results
- Business plan for EV market
- Technology development roadmap

**Partners**  
BrillPower, ecor, sustainable ventures

**Project innovations**

- Three main innovations were developed on this project:
  - Analysis of EV battery lifespan using field data
  - Development and testing of updated Battery Management System
  - Development and testing of Brill Power value proposition

**Contact:**  
Chris Jones Email: chris@brillpower.com Web: www.brillpower.com  
John White Email: john@brillpower.com Web: www.brillpower.com  
Sustainable Ventures Email: info@sustainableventures.co.uk Web: www.sustainableventures.co.uk

### Faraday precision ageing laboratory

Delivering fully factored, long-term cell ageing & degradation studies - on a scale not previously achieved before.

**Project costs**  
Total project costs: £4,079,910  
Grant contribution: £3,861,017

**Executive summary**

The requirements that underpin the EV battery ageing and degradation are not well understood. There is limited availability of validated data on individual ageing mechanisms and even less data on the inter-dependency of ageing mechanisms and cell characteristics. This is a major impediment to the UK battery industry as current state-of-the-art ageing and degradation models cannot provide the required level of precision. Through Faraday Battery Challenge funding, a new test facility has been established to specifically address this threat to the UK battery industry. The Faraday Precision Ageing Laboratory is dedicated to long-term, long-term cell ageing & degradation studies - on a scale not previously achieved before. There are three main objectives:

- The creation of a UK repository of battery ageing and degradation datasets. These datasets will help to support and accelerate the development of machine learning and Artificial Intelligence (AI) battery ageing algorithms.
- The development of new fully validated and parameterised, high accuracy ageing and degradation models. As the data repository expands over time, models will be available for different cell chemistries, use cases and form factors.
- The generation of new knowledge and a better understanding of electrochemical ageing mechanisms through forensic autopsy and physical validation of ageing mechanisms.

**Timeline with milestones and deliverables**

November 2017 Project Start (Building awarded)  
December 2017 Equipment ordering  
March to August 2018 Equipment delivery and commissioning  
March 2019 First experimental rigs completed  
April 2019 Facility first tests started

**Deliverables:**

- 1,344 cell level cyclers channels - 0-6V, 10A intended for long term ageing
- All high power cell cycler channels - 0-6V, 200A intended for periodic cell characterisation
- 64 channel expandable Electrical Impedance Spectroscopy (EIS) Equipment for in-situ testing
- 31 recirculating heat exchanger units - to support high precision, fully immersed thermal management test rigs
- 8000L Level 20 generic test chambers - intended for high power cell testing
- 10 thermal storage chambers - intended for long term calendar ageing
- Dedicated IT infrastructure - secure, access controlled, replicated data storage and networking
- Experimental rig designed, high precision, fully immersed thermal management rigs for accurate management of cell temperature during long term ageing experiments.

**Partners**  
WWMG

**Project innovations**

- First ever comprehensive, fully factored, long term ageing & degradation study
- Market leading high channel density cell cycler technology
- Unique experimental rig design with fully immersed thermal management

**Contact:**  
John White Email: john.white@brillpower.com Phone: +44 (0)1753 23517

### The Voltt: Optimizing EV Battery Lifetime with Advanced Modelling Technologies

By better predicting the aging of lithium-ion batteries used in electric vehicles, this project will reduce the total cost of ownership of systems and improve the sustainability of battery development.

**i-CoBat: Immersion Cooling of Battery Modules with a synthetic ester dielectric liquid**

Development of an immersion cooled battery module for PHEVs and BEVs

- Customised cell selection
- Performance optimisation
- Module and pack design optimisation

**Partners**  
IMI MATERIALS, VOLT, WWMG

**Partners**  
ABOUT ENERGY, Imperial College London

**Partners**  
WWMG

[www.ukri.org/publications/faraday-battery-challenge-funded-projects/](http://www.ukri.org/publications/faraday-battery-challenge-funded-projects/)



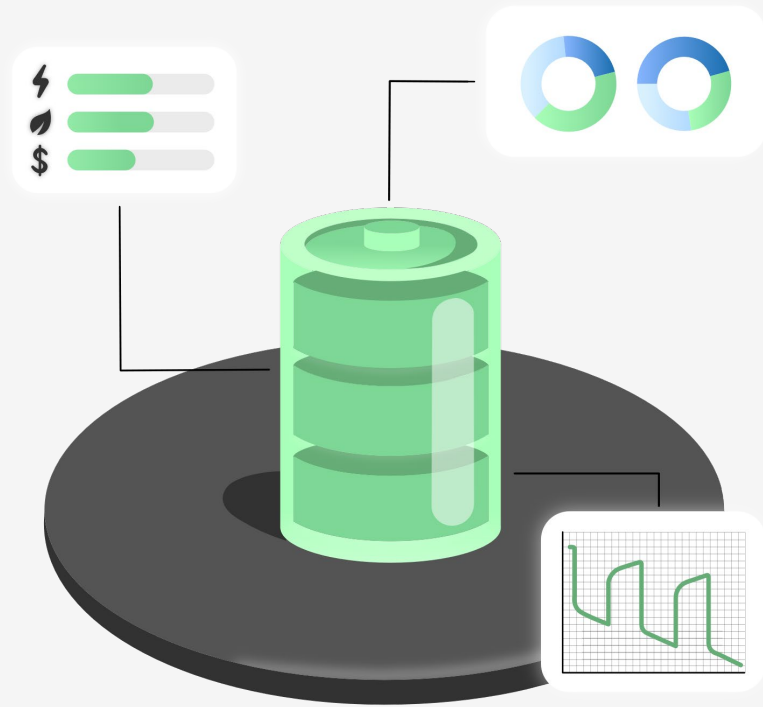


# Thank you

[matt.stock@iuk.ukri.org](mailto:matt.stock@iuk.ukri.org)

[faradaybatterychallenge@iuk.ukri.org](mailto:faradaybatterychallenge@iuk.ukri.org)





# ABOUT:ENERGY

## Accelerating Electrification

# How to help your batteries



**Store cold, use hot**



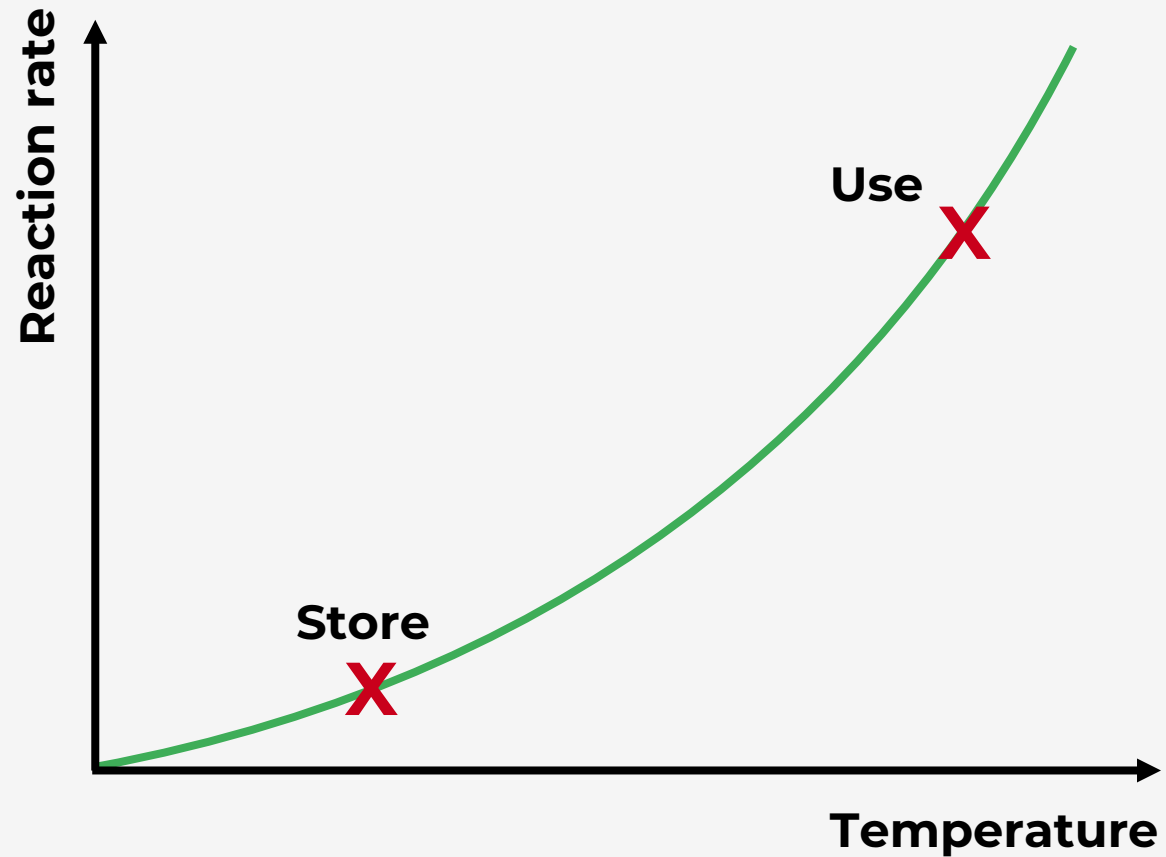
**Charge slow**



**Store half-full**



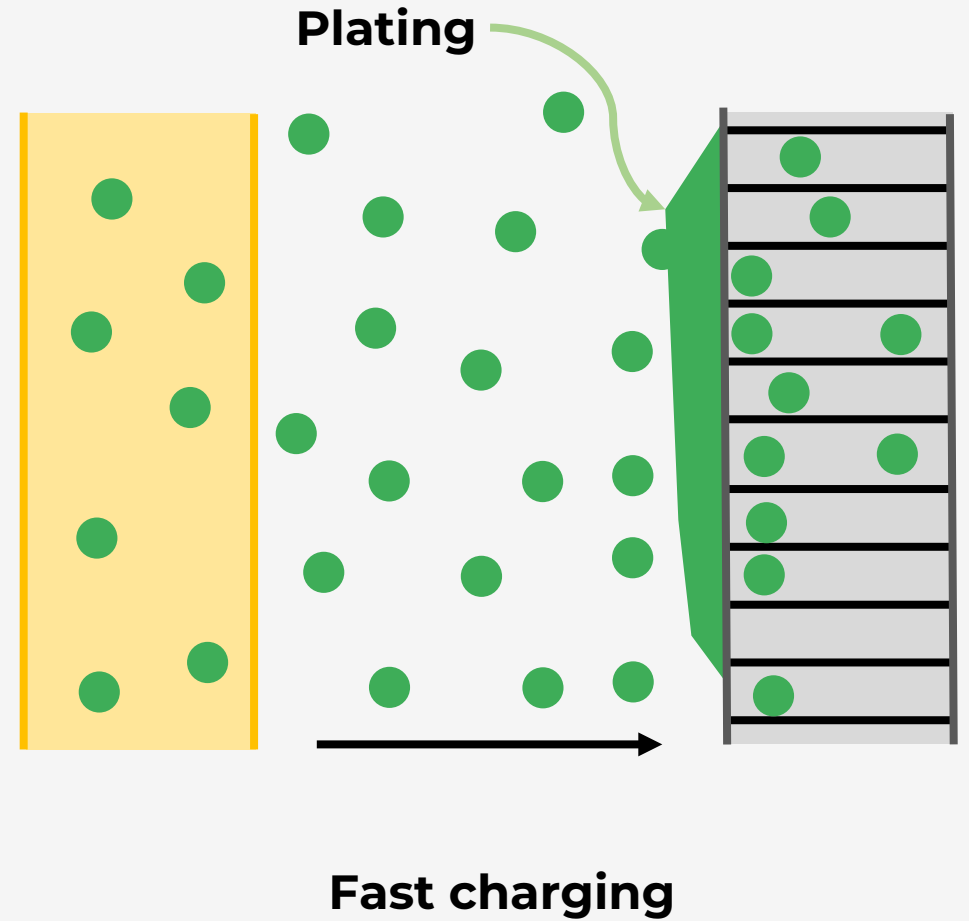
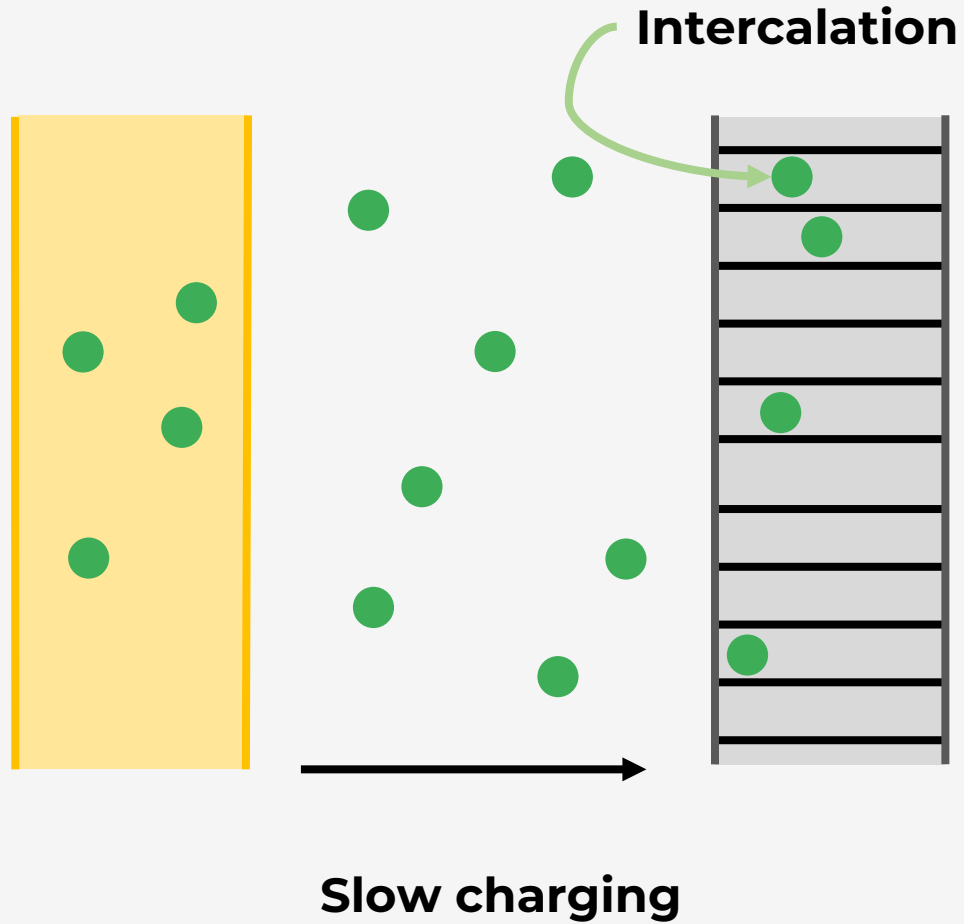
**Store cold, use hot**





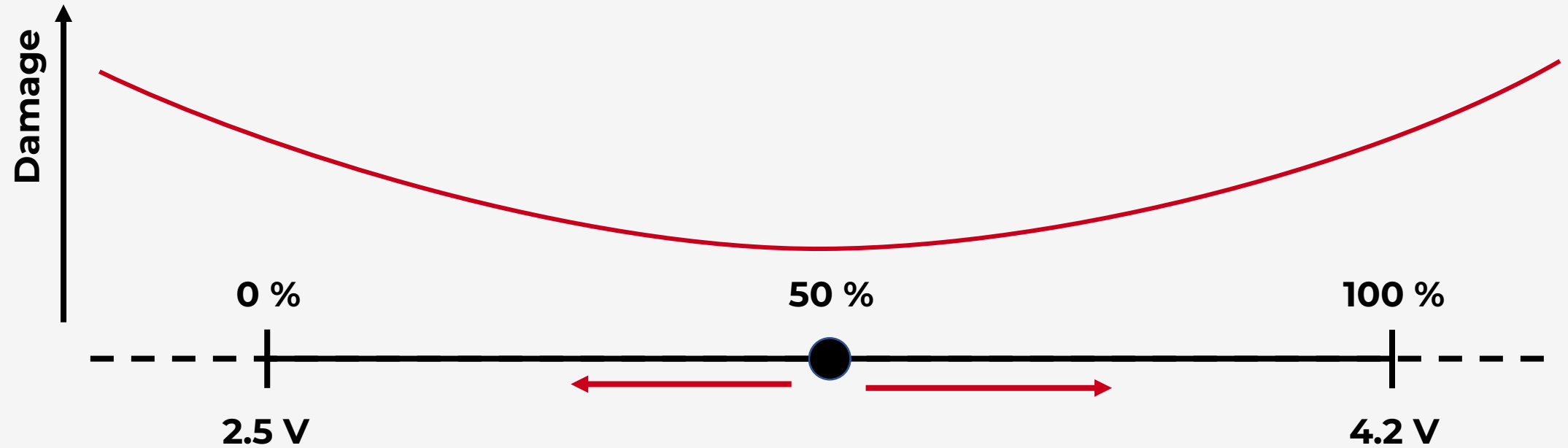


## Charge slow

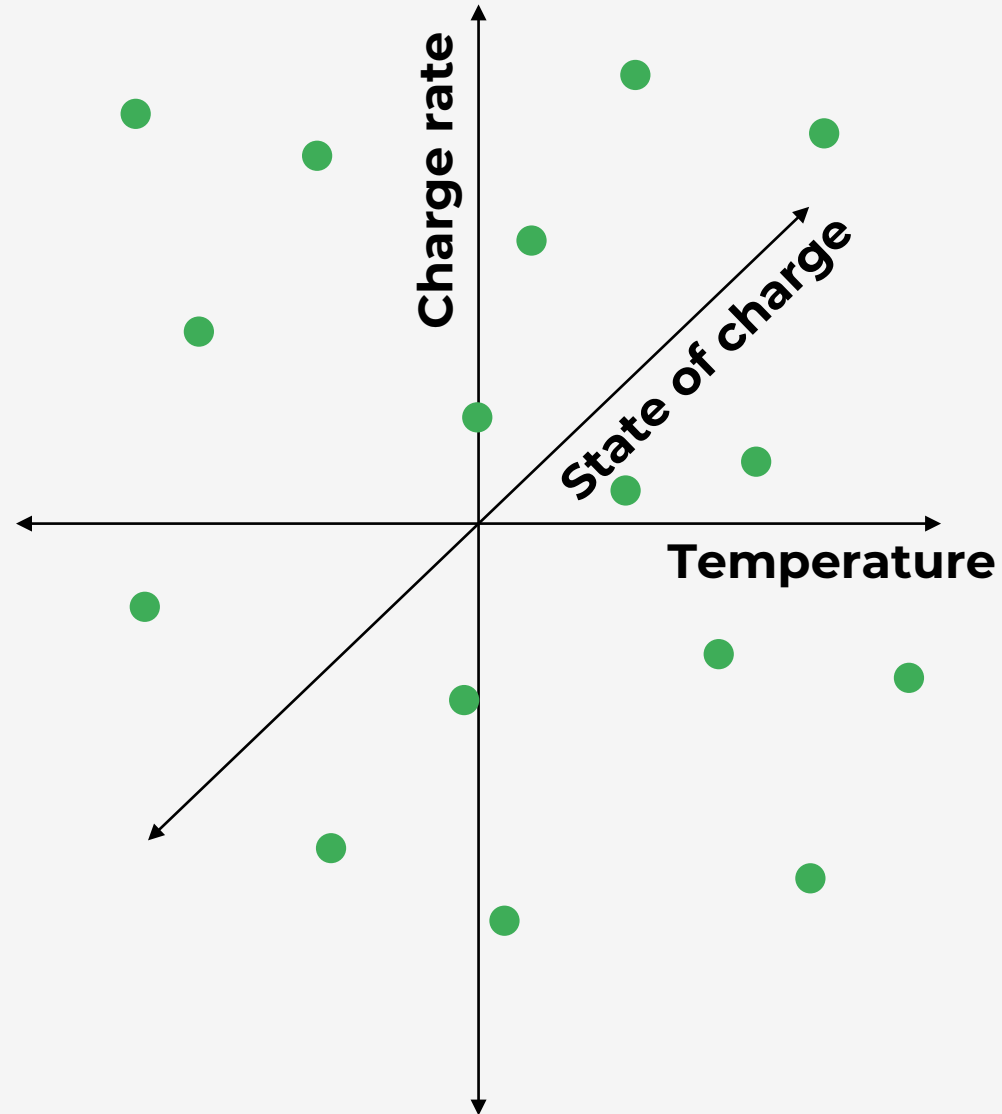


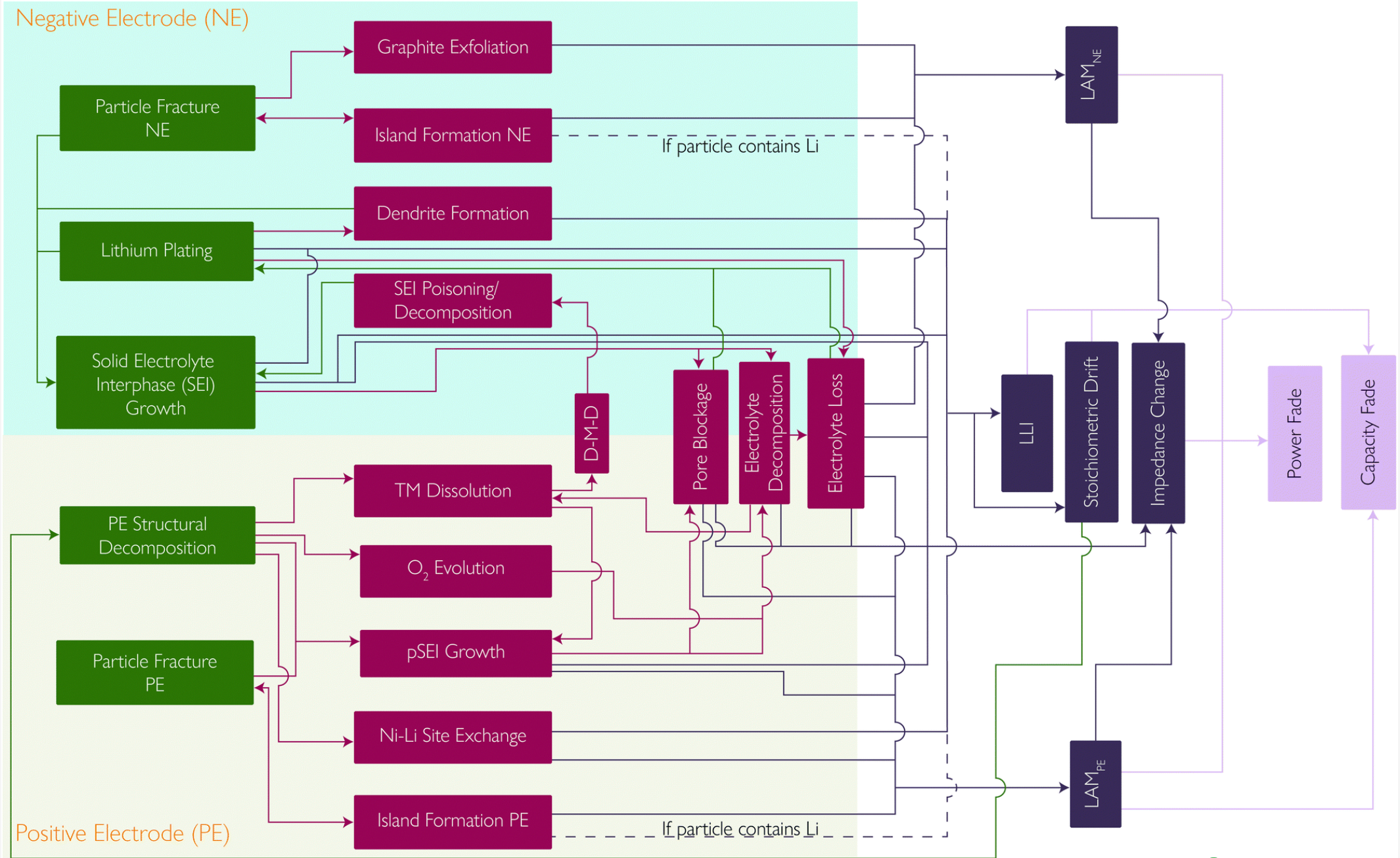


**Store half-full**



# Degradation gets complex





Source: J. Edge *et al.* (2021) "Lithium ion battery degradation: what you need to know"



# How we help

Thermal control

Cell cycling protocols

Teardown

Modelling



## Industry-leading models



Electrical



Thermal



Electrochemical



Degradation

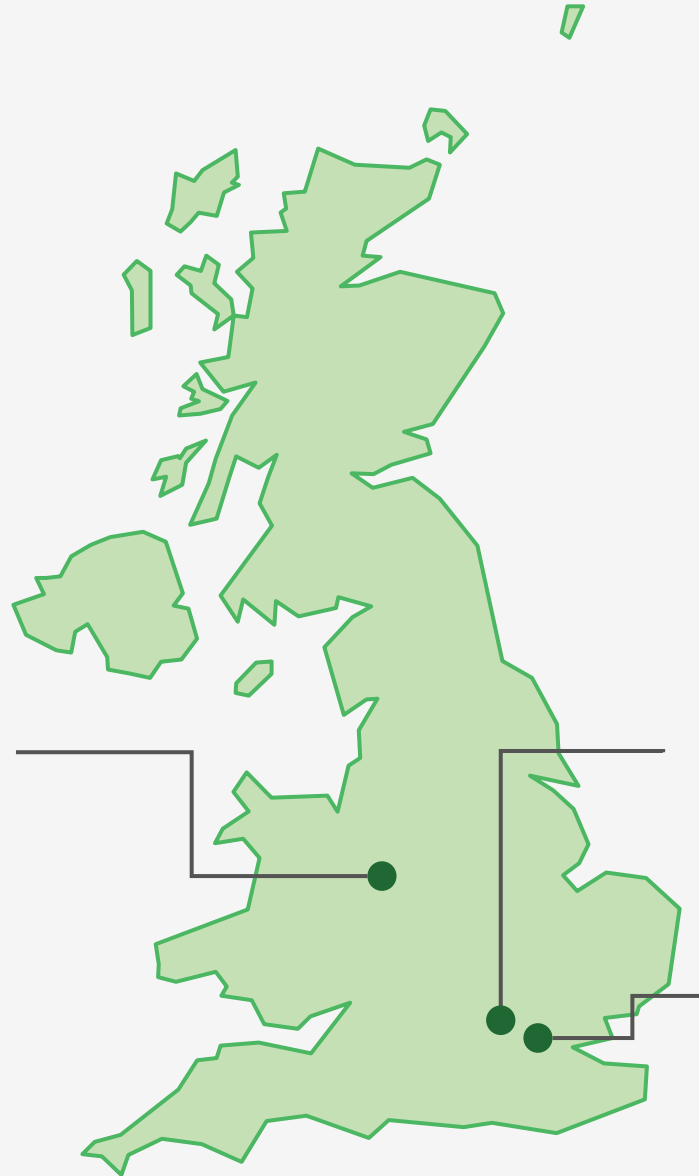
## Large database

**500+** Commercially available cells

# Who are we?



UNIVERSITY OF  
BIRMINGHAM



THE FARADAY  
INSTITUTION

Imperial College  
London



# Takeaways



**Store cold, use hot**



**Charge slow**



**Store half-full**



# Panel: Battery Degradation



Marc Palmer  
Autotrader



Scott Raffan  
Geotab



Dr Matt Stock  
Innovate UK



Gavin White  
About: Energy



Department  
for Transport

# **DfT battery health regulations update**

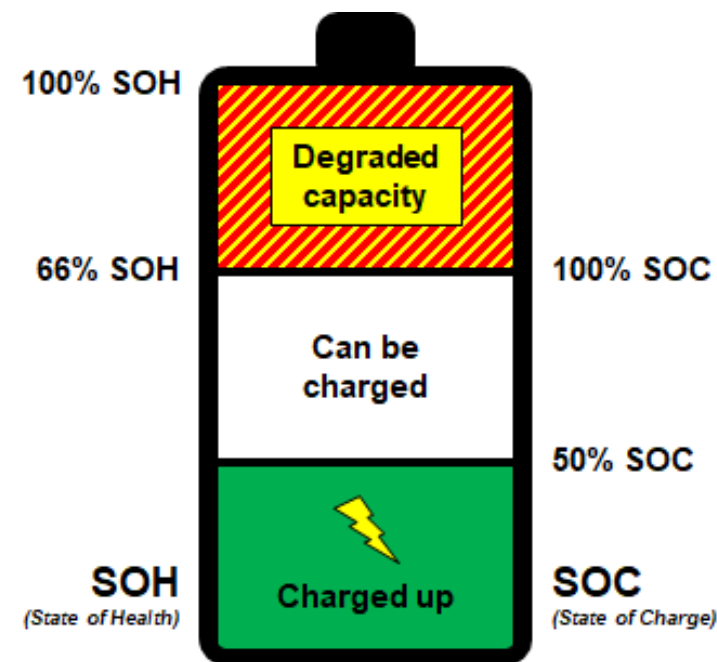
**Adam Dack**

**Senior Engineer, Vehicle Environmental Standards**

**16 May 2023**

# Overview

- **Global Technical Regulation No. 22**
  - Introduction to UNECE
  - Background
  - Approach
  - Global views on implementation
  - Future work
- **Research update: existing EVs**
  - Scope and objectives
  - Initial insights
- **Summary**



# Global Technical Regulation No. 22

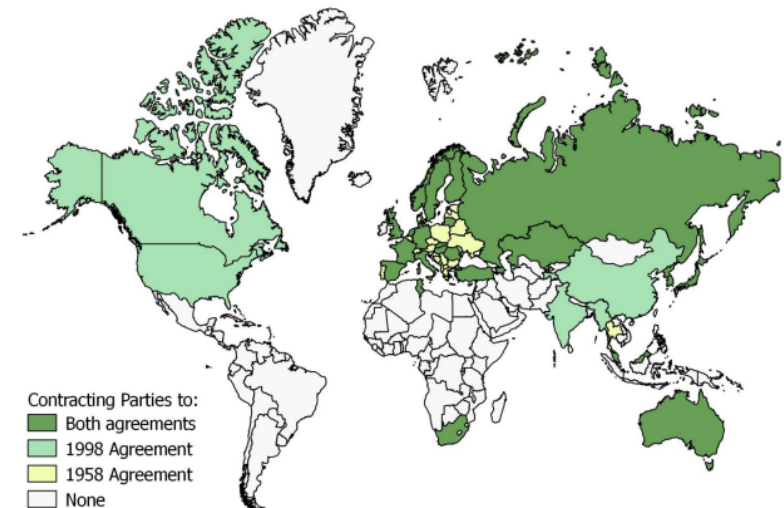


# GTR22: Introduction to UNECE

- The United Nations Economic Commission for Europe (UNECE) established to promote **economic cooperation** and **integration**
- ~80% of UK vehicle regulations are developed via the UNECE's **World Forum for Harmonisation of Vehicle Regulations**

• **Global Technical Regulations** (GTRs) provide a regulatory framework, typically containing harmonised **test procedures** and **requirements**

- UN Regulations are similar to GTRs, but also include administrative procedures for **type approval** and **mutual recognition**

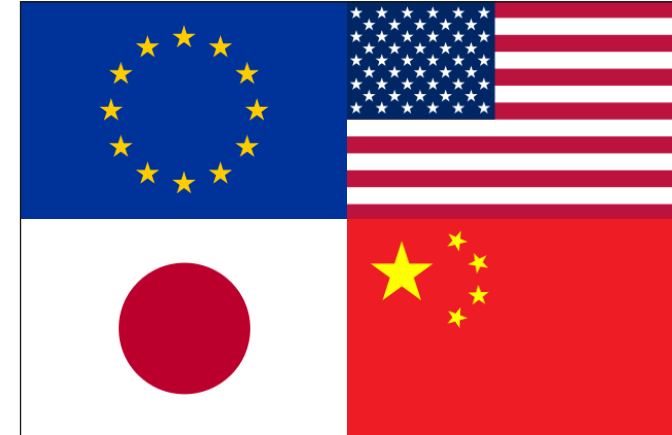


# GTR22: Background

- UN GTR No. 22 on *In-vehicle Battery Durability for Electrified Vehicles* published in 2022 (openly available [online](#)), with key input from DfT

- **Aim:** Develop a battery durability standard for new BEVs/PHEVs to ensure that inferior products do not enter the market

- Secondary benefits could include:
  - Improved consumer confidence in **performance over time**
  - Improved confidence once vehicles reach **second-hand market**



# GTR22: Approach

## Part A

- Mandates installation of state of health (SOH) monitors and **accessible display** to consumer
- Requires the SOH monitors to meet an **accuracy** requirement
- Validate accuracy of SOH monitors over time/mileage through **in-service testing** against regulatory test cycle (WLTP)

## Part B

- Adopt a minimum performance requirement (MPR) for battery durability:
  - Min. 80% capacity remaining **after 5 years** or 100,000 km (62,000 mi)
  - Min. **70% capacity** remaining **after 8 years** or 160,000 km (100,000 mi)
- Validate MPR is met by assessing SOH values on vehicles in service (e.g., via MOT or over-the-air telematics)
- Use a statistical process to determine pass/failure for a vehicle model

# GTR22: Global views on implementation

## USA/Canada

- EPA included GTR in their next emissions package, starting in **2027**
- Canada likely to follow USA timeline

## European Union

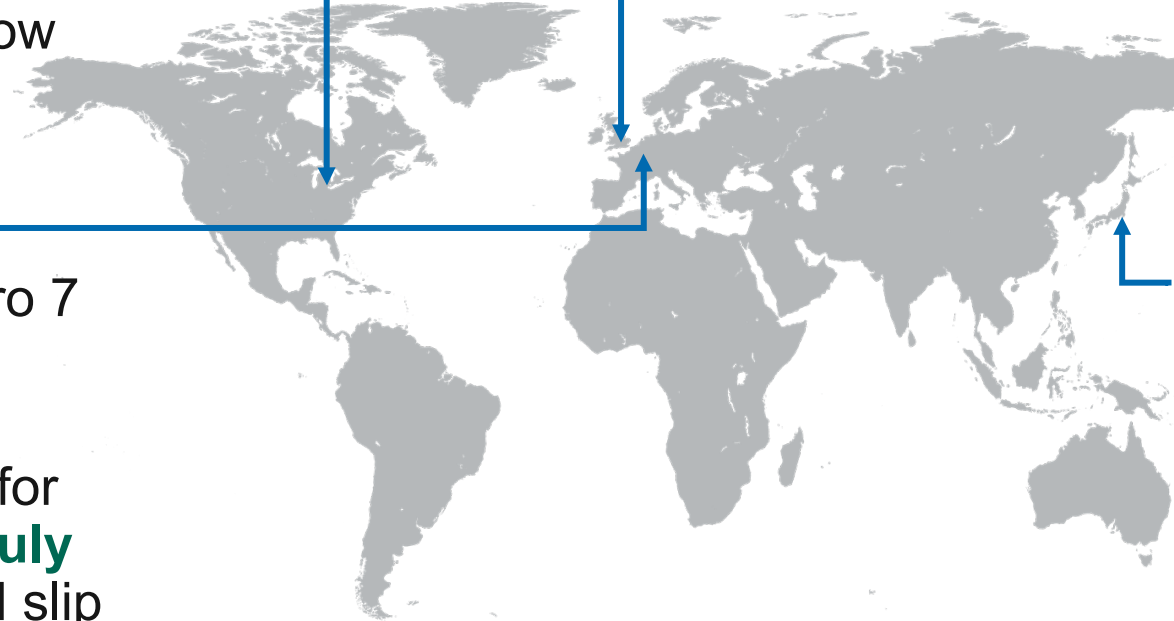
- GTR included in Euro 7 package
- Euro 7 proposed to become mandatory for new vehicles from **July 2025**, but date could slip

## UK (GB)

- Considering options for implementation
- Currently conducting analysis on benefits of UK implementation

## Japan

- SOH monitors to be required from **October 2024**
- Implementation dates of other aspects of GTR to be confirmed





# GTR22: Future work

- Conducting analysis on the benefits of implementing GTR22 in the UK, while continuing other work through the UNECE
- Currently only **passenger cars** and **light commercial vehicles** (LCVs) are in scope of the GTR
- MPRs are still to be agreed for LCVs, with manufacturers citing their **varied duty cycles and use cases**
- Work ongoing to develop a separate GTR for **electric heavy-duty vehicles**, expected to be published in late 2024



# Research update: existing EVs

# Research update: Scope and objectives

- What can be done for **existing EVs**?
- DfT researching **accessibility** and **comparability** of on-board battery health information for a wide range of used EVs
- **30 used EVs**, including BEVs and PHEVs, cars and vans, model years 2017 through 2021
- Probe vehicles for any **on-board information**, e.g., via dashboard, OBD tools, CAN bus
- Perform **GTR22 battery health test** and compare against on-board information



# Research update: Initial insights

- Early results suggest **very limited accessibility**, often requiring specialist equipment and/or tools
- Comparability also looks to be a challenge; different battery management systems will estimate battery health in different ways
- Challenges with accessibility and comparability demonstrate a need for **standardisation** (e.g., as provided by GTR22)
- **Analysis is ongoing**, further results to follow later this year





# Summary

- If GTR22 is introduced in the UK, battery health information will be **accessible** and **comparable** across vehicle models and manufacturers
- However, effect on second-hand market not likely to be seen for several years
- DfT is researching provision of battery health information in **existing EVs**, but accessibility and comparability are key challenges
- Battery health certificates may offer some utility, but **exercise caution** when comparing results from different vehicle models and manufacturers





slido



## Audience Q&A Session

ⓘ Start presenting to display the audience questions on this slide.



# Latest on The Road to 2030

MARC PALMER, AUTO TRADER

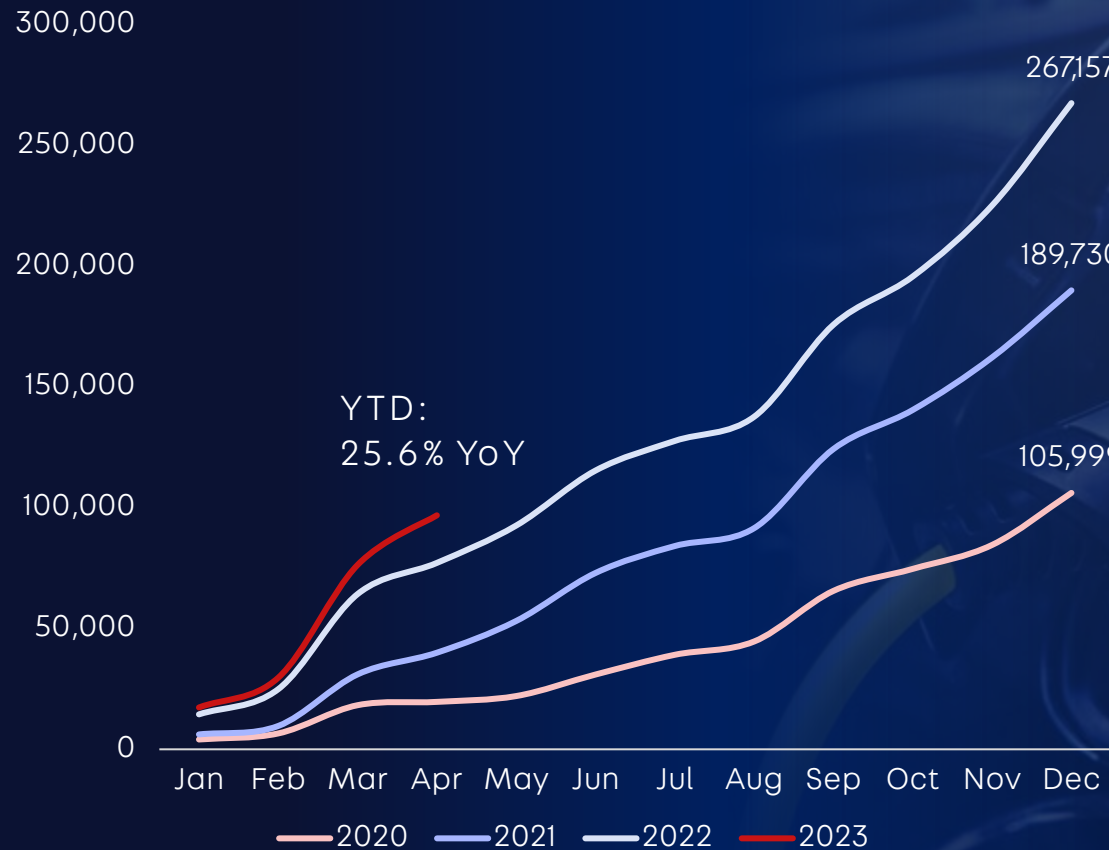
A man and a woman are looking at a car. The man is on the right, smiling, and the woman is on the left, also smiling. They are both looking towards the car. In the background, there is an American flag. The entire image has a dark blue overlay.

# 01 The new EV market

# Fleet continues to drive new EV sales with retail more limited - electric's market share has flattened recently

## CUMULATIVE NEW EV SALES

SMMT



## EV SHARE OF NEW CAR SALES

SMMT



# Consideration for new EVs on Auto Trader is improving but remains subdued. Only 9% of new car leads are on EVs (down 11ppts year-on-year)

## EV SHARE OF NEW CAR MARKET ON AUTO TRADER





There are now 76 new electric models available to buy in the UK. Choice is limited compared to ICE models, but the gap is closing

76

Different electric car models available

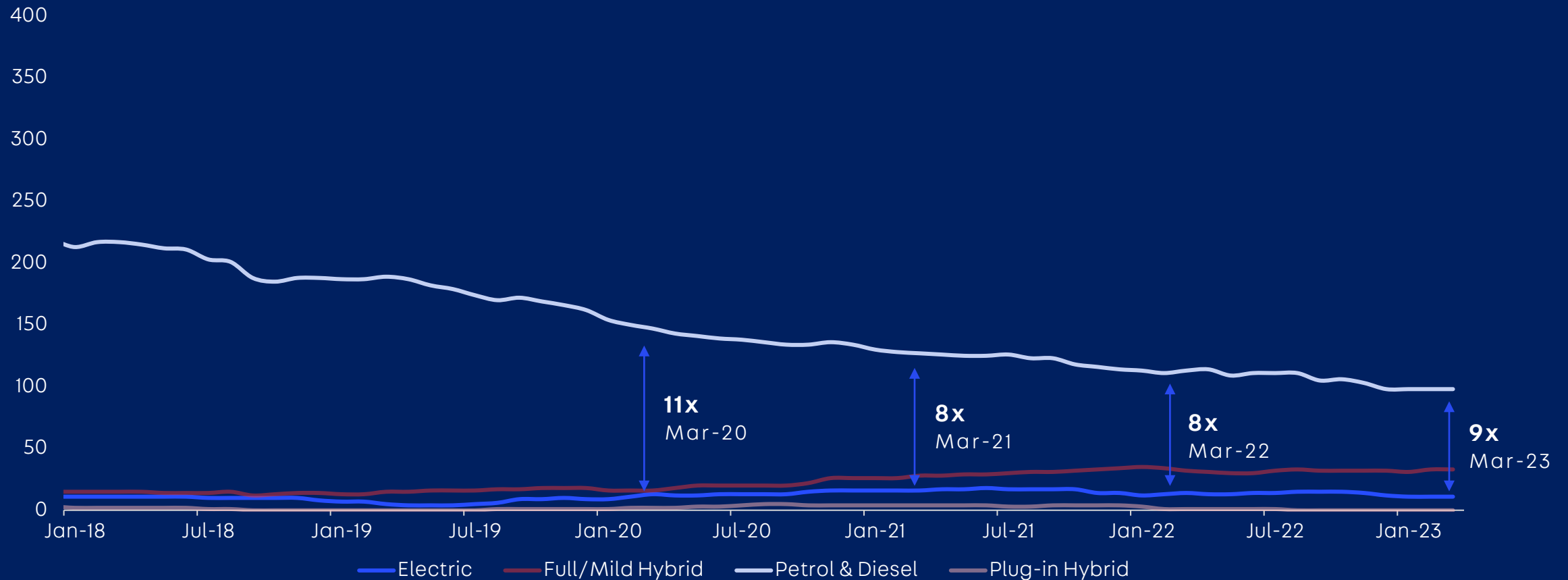
4x

More ICE models - was 11x 3 years ago

# Not enough affordable new EVs with 9x more new ICE cars for under £30k vs electric - the gap isn't closing quickly

## NUMBER OF NEW CAR MODELS AVAILABLE TO BUY IN THE UK FOR UNDER £30K (RRP)

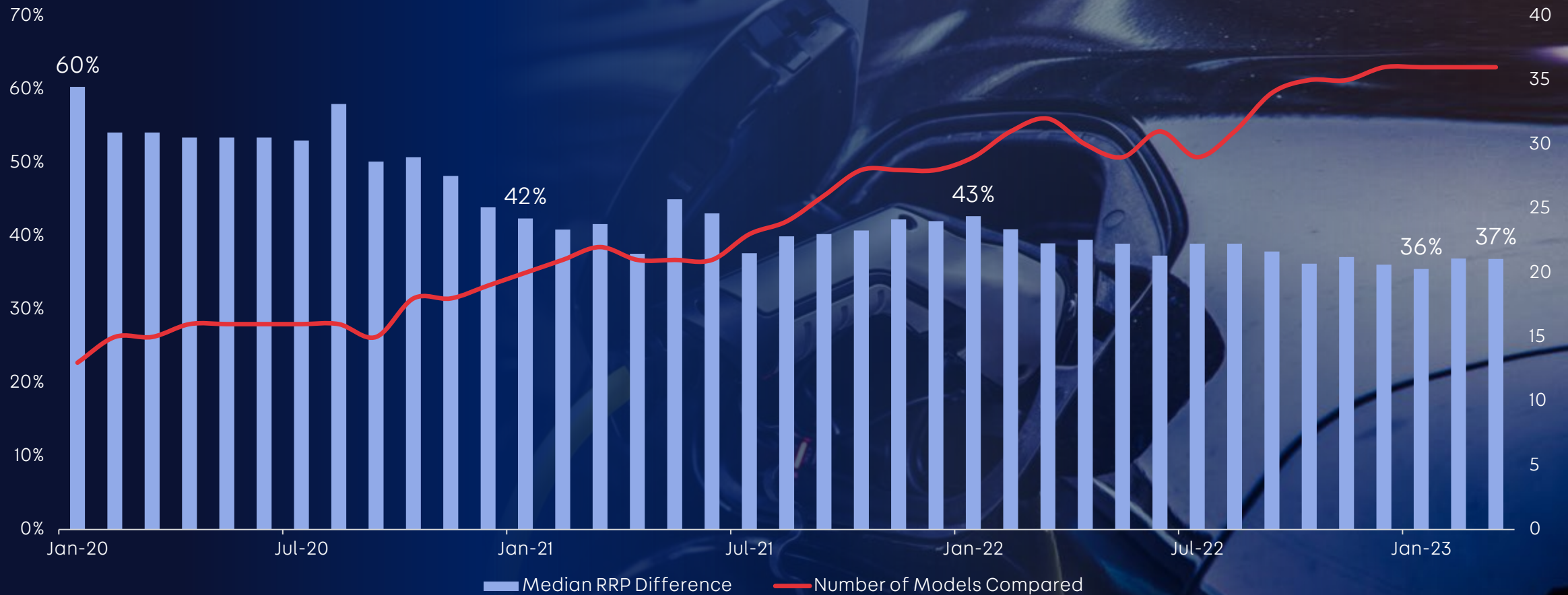
All manufacturers



# Like-for-like, new EVs are still around 37% more expensive than ICE

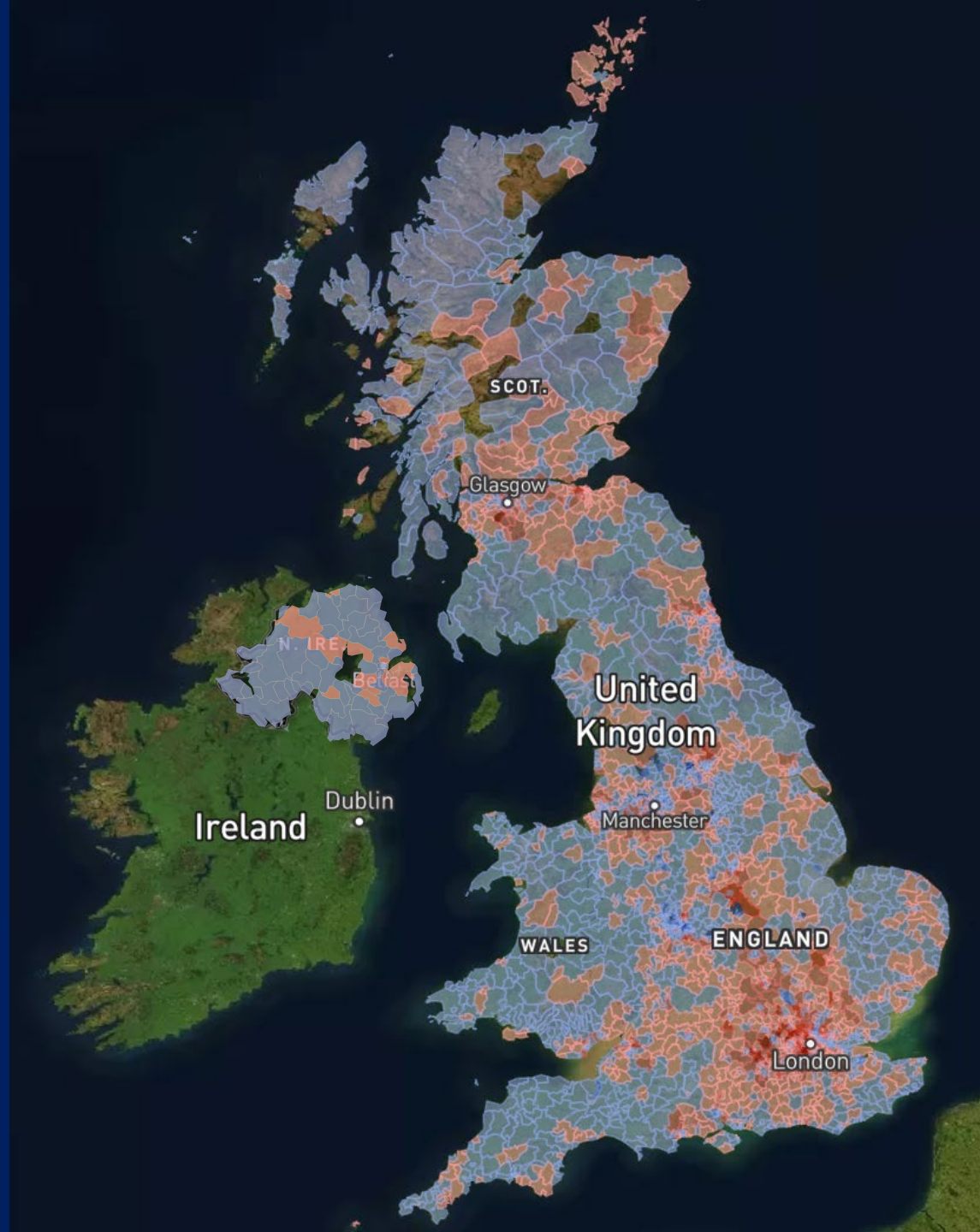
## UPFRONT PRICE DIFFERENCE (RRP): NEW ICE VS. NEW EV

Like-for-like model comparisons





Demand for EVs is still spread across the UK's affluent areas.







# THE ROAD TO 2030

- > Retail demand is subdued, with share of leads taken by EVs halved YoY
- > Choice is increasing, but hasn't yet reached more affordable levels
- > Retail demand is still located in affluent areas, with little sign of mainstream interest



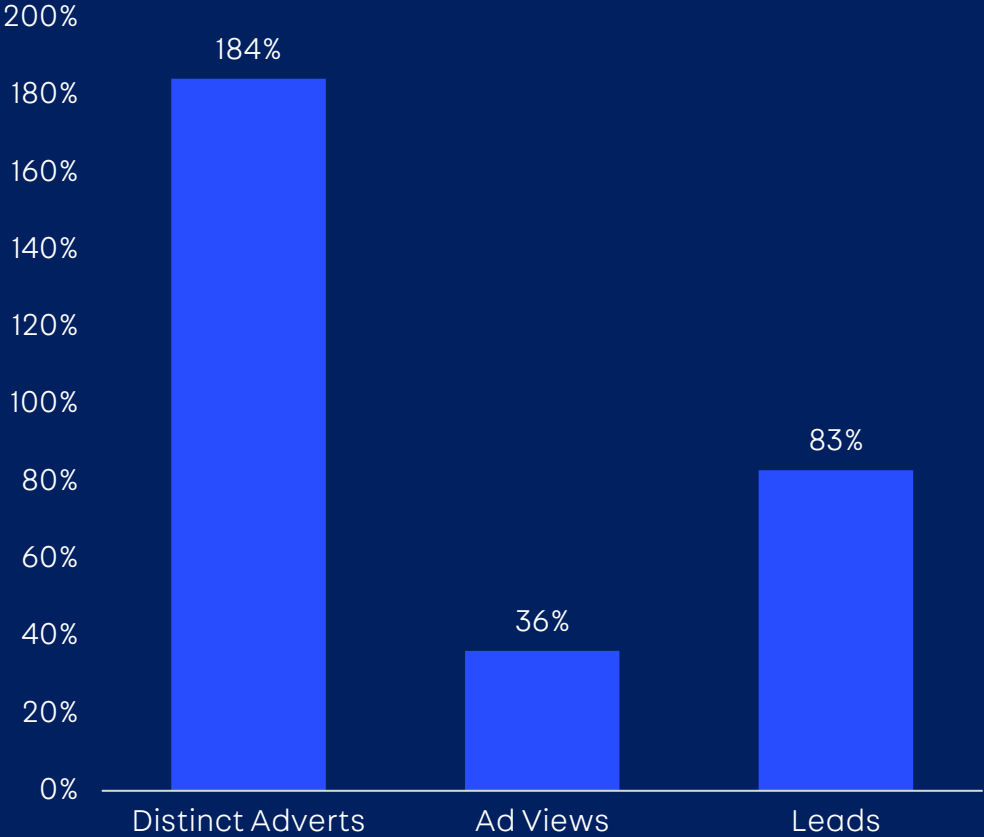
A man and a woman are smiling and looking at a car. The man is on the right, and the woman is on the left. An American flag is visible in the background. The image is overlaid with a dark blue semi-transparent layer.

# 02 The used EV market

# Demand for used EVs is ahead YoY, but outpaced by supply, with daily average volumes up by c.10k

## USED EV ACTIVITY: YEAR-ON-YEAR

April-2023



## NUMBER OF UNIQUE USED EV ADVERTS

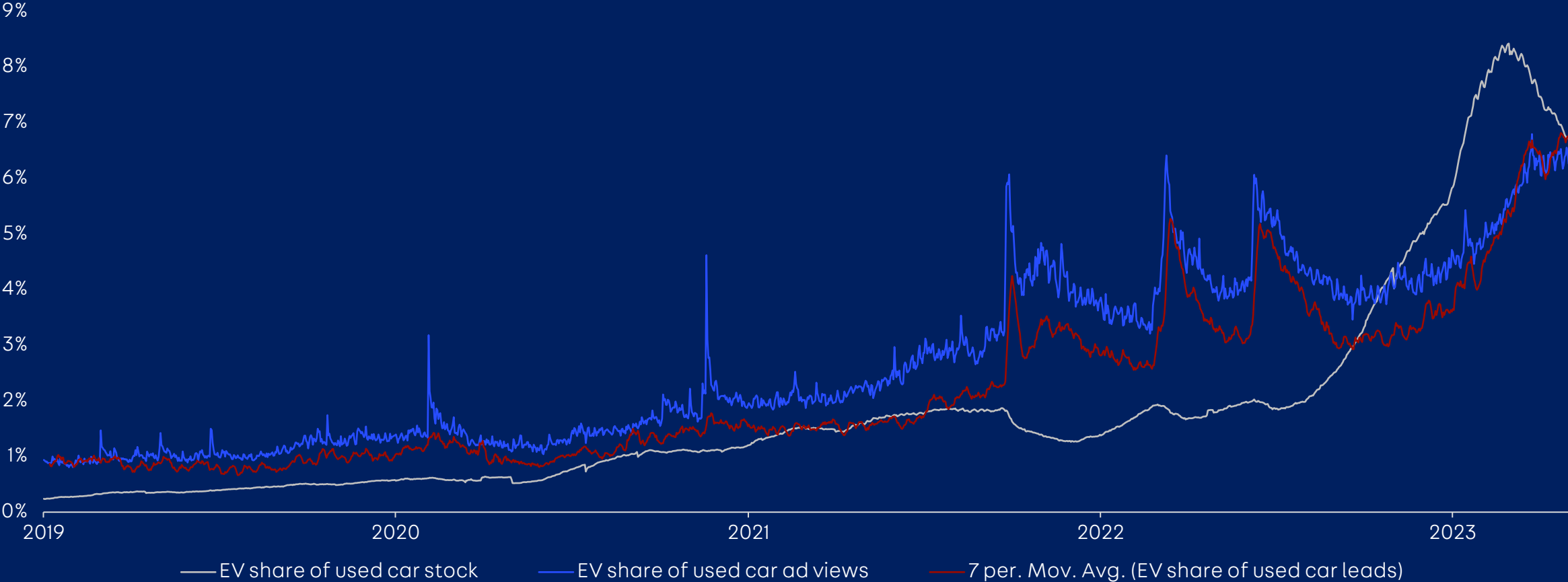
Advertised on Auto Trader.



# Supply and demand dynamics have improved in recent weeks - demand has risen as prices fall

## EV SHARE OF USED CAR MARKET ON AUTO TRADER

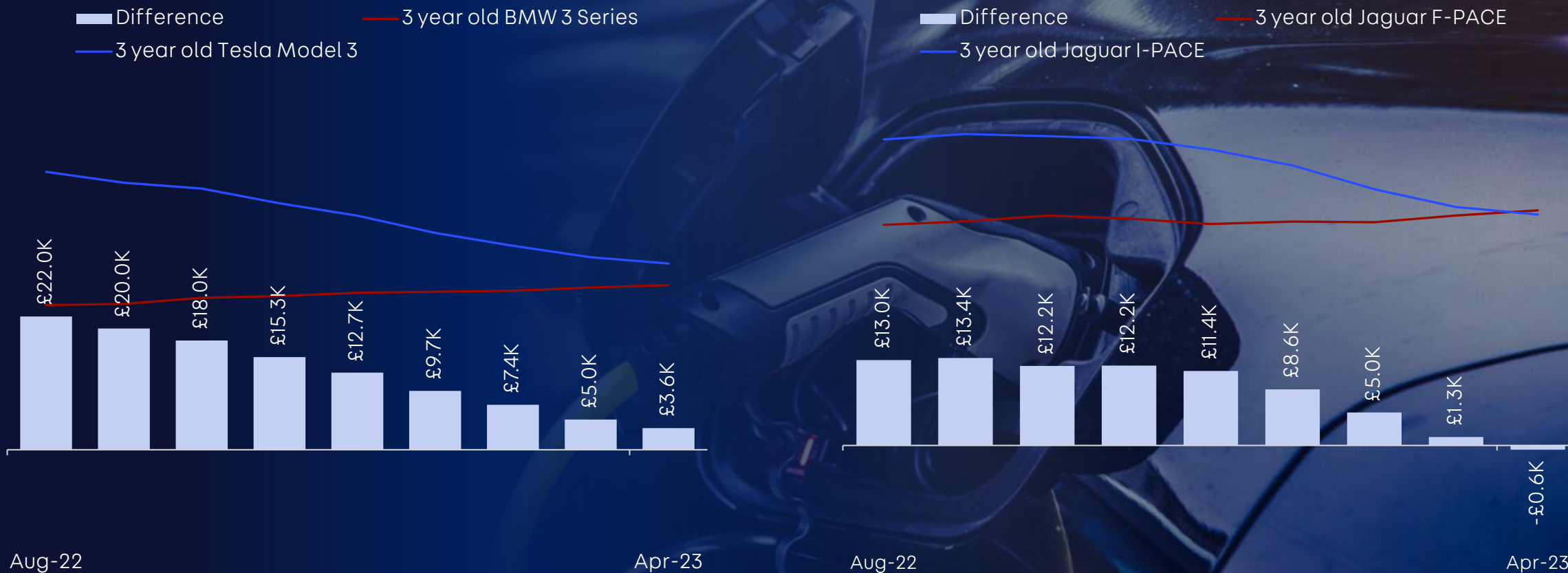
0-5 years old.



# The price gap has closed considerably - some electric models are now being cheaper than their ICE equivalents after three years

## EV VS. ICE ADVERTISED PRICES AFTER THREE YEARS

Average prices

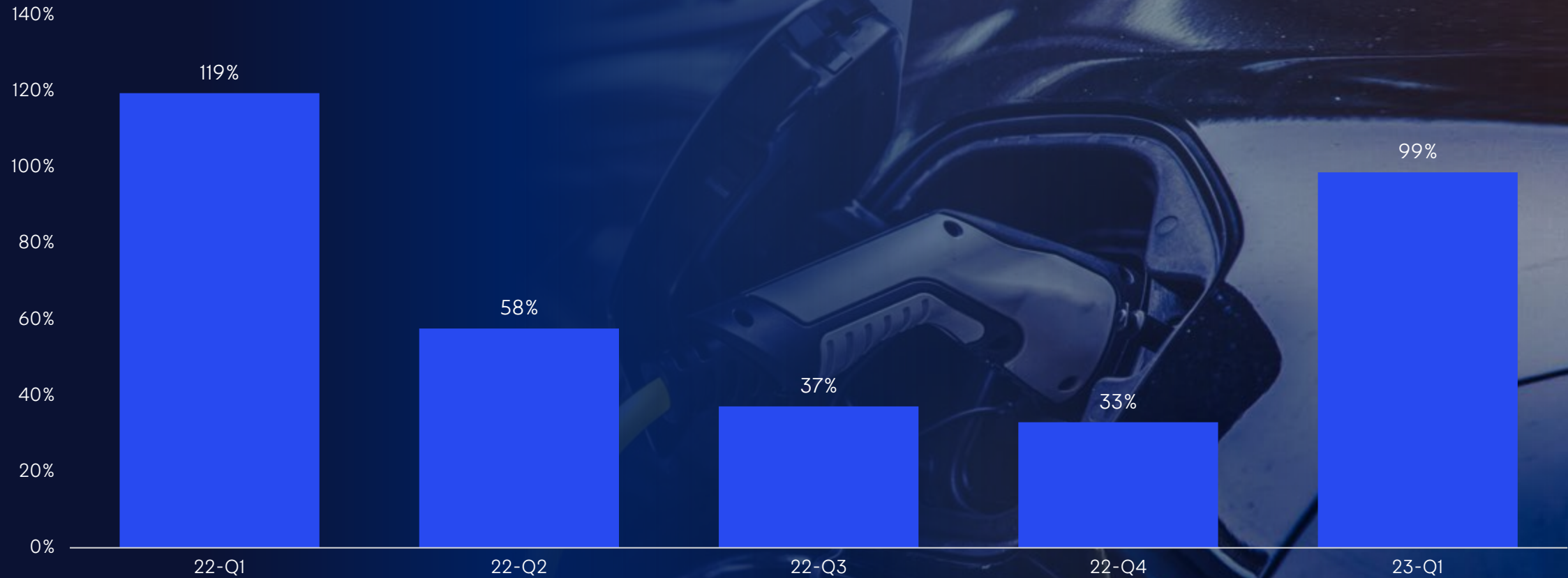




# Leading to more sales in Q1 with volumes doubling YoY - 2.3% used sales are now electric

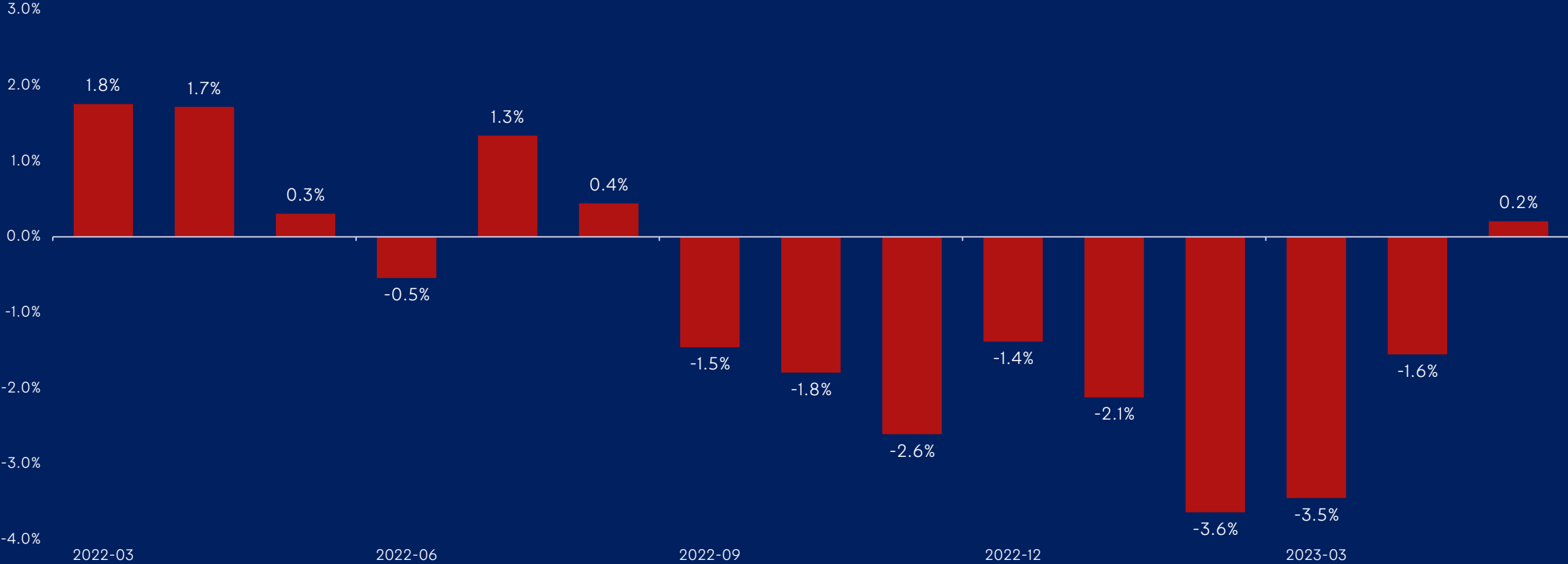
## USED ELECTRIC CAR SALES: PROXY YOY

Based on the cars removed from Auto Trader



# Month-on-month used EV prices fell for eight consecutive months – but latest data shows a slight recovery

## USED CAR RETAIL PRICE GROWTH Month-on-Month



Future RVs on electric vehicles were very strong before supply ramped-up, but have dropped recently in response to the market

**FUTURE RETAIL RESIDUAL VALUES BY FUEL TYPE: 3 YEARS, 30K MILES**


1<sup>st</sup> day of each month snapshot







# THE ROAD TO 2030

- > Used EV demand is up and leads have grown by 83% YoY – positive signs
  - > Supply is +184% - this is impacting speed of sale, with electric the slowest-selling fuel type
  - > Prices have fallen 18% YoY, leading to a significant drop in the upfront price gap to ICE
  - > Signs that this phase of maturation is impacting future values
- 



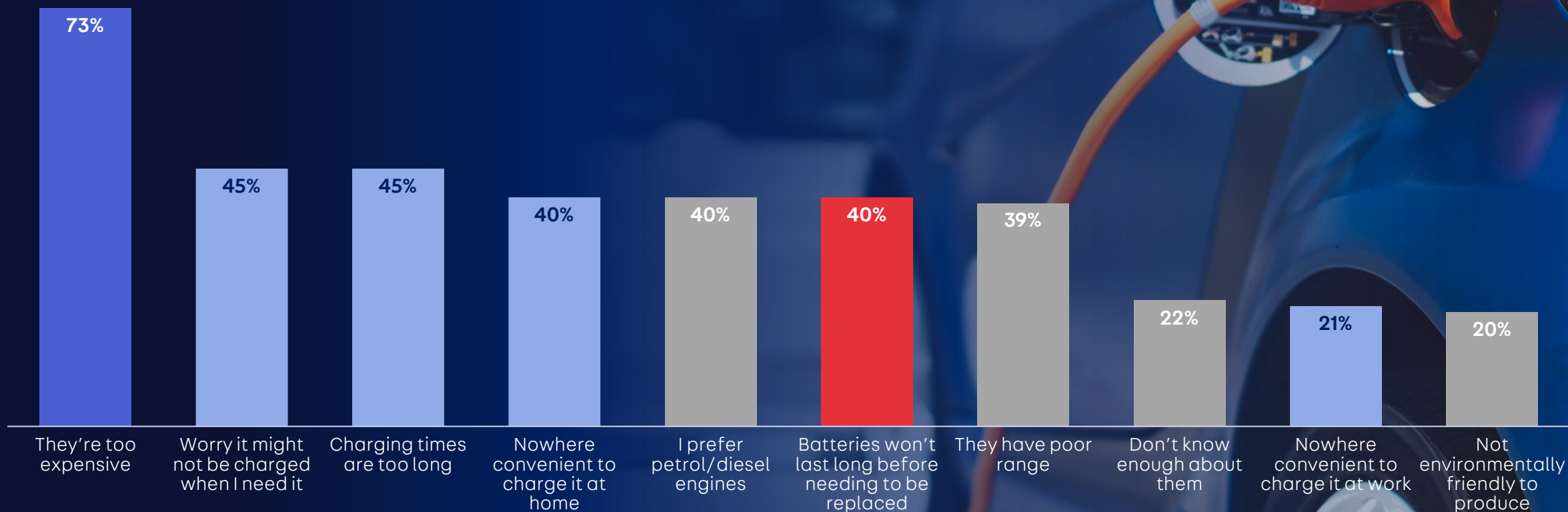
A man and a woman are shown in profile, smiling and looking at a laptop screen. The background features an American flag. The entire scene is overlaid with a dark blue semi-transparent filter.

# 03 Barriers to adoption

# Reasons to reject are numerous - 3 in 4 say cost puts them off, 40-45% cite charging concerns and 40% worry about batteries

## REASONS TO NOT CONSIDER AN ELECTRIC CAR

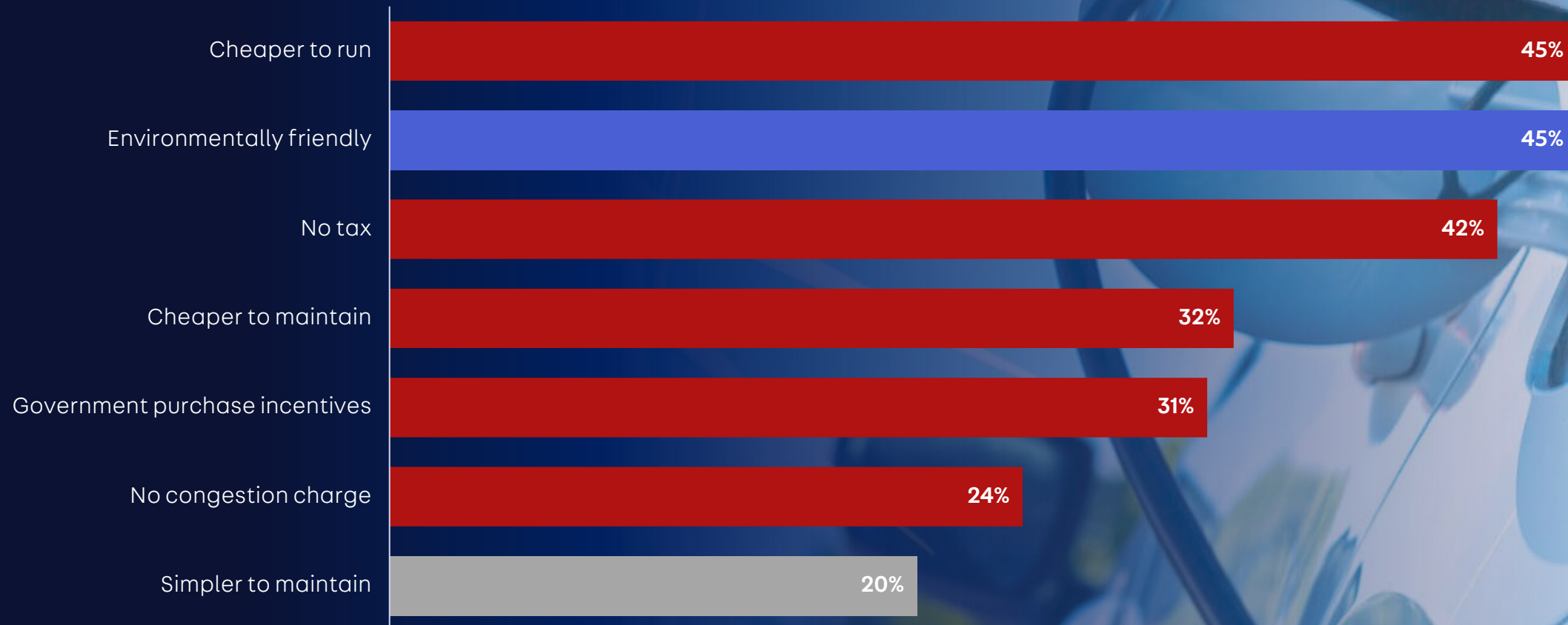
Multiple answers



# The big thing to get rejectors to consider in future is cost

## REASONS TO CONSIDER AN ELECTRIC CAR IN FUTURE

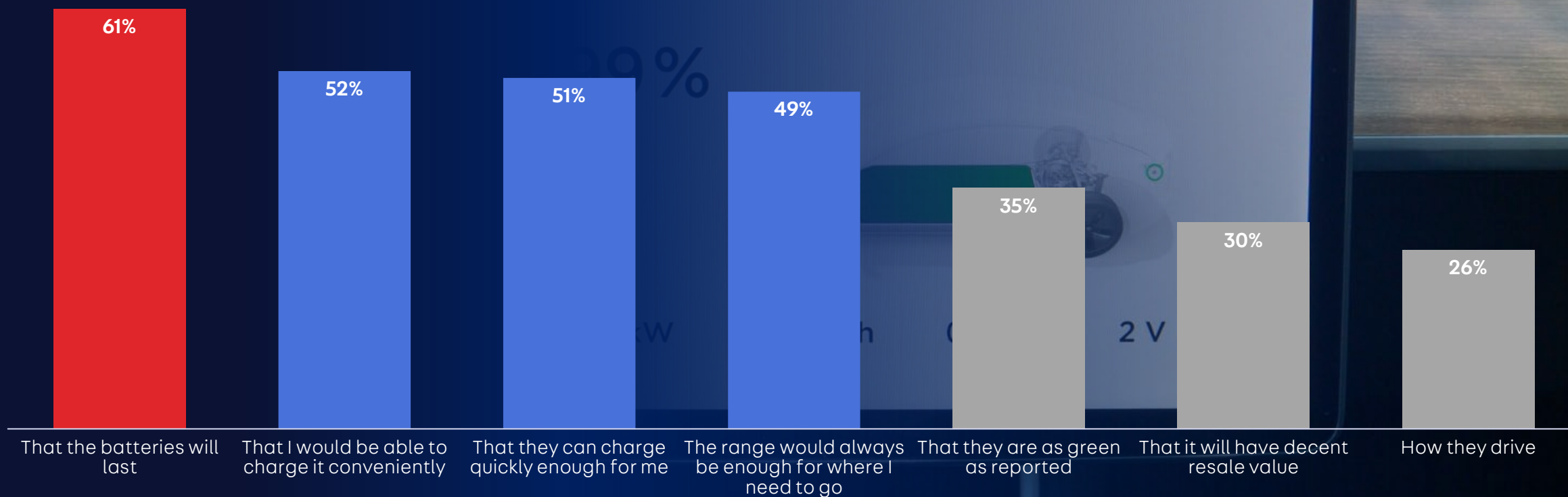
Multiple answers



# And the information they need is battery reassurance and charging

## WHAT INFO THEY NEED TO CONSIDER AN ELECTRIC CAR


Multiple answers







# THE ROAD TO 2030

- > Cost of buying and running is a reason to reject for three quarters
  - > Cheaper running costs and incentives to buy are the main reasons to consider in future
  - > Battery health is the top information need, with charging info next
- 

 AutoTrader



# Panel: Battery Health Certificates



Catherine Bowen  
BVRLA



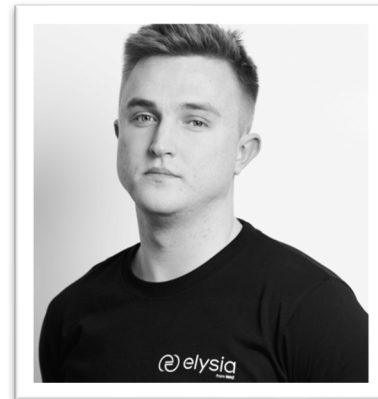
Thomas Mulon  
MOBA



Tobias Huelsing  
Bosch



Patrick Cresswell  
ClearWatt



James Wallace  
WAE



Alex Johns  
Altium



mobba



What is the difference between these two vehicles ?



**Renault Zoé Life R90**  
**£13,500 - 12,000 miles - 2017**

Published on May 10th 2023 at 13:33



**Renault Zoé Life R90**  
**£13,500 - 12,000 miles - 2017**

Published on May 10th 2023 at 13:33

## The battery State of Health!



**Renault Zoé Life R90**

**£13,500 - 12,000 miles - 2017**

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**Renault Zoé Life R90**

**£13,500 - 12,000 miles - 2017**

Published on May 10th 2023 at 13:33

# Our solution : Moba Certify Pro

The first trusted third party that certifies the battery State of Health of EVs

**MOBA CERTIFY PRO** Available credits : 67 Buy credits

Search Filter Q4 2022 237 diagnosis Download XLS

VIN	Model	SOH	Type	Date	Site	Team	Operator
SV3ZU7*****98	Model 3	99%	Certificate	02/10/21 10h37	Nantes	team a	Jean (report)
SV3ZF7*****71	Model 3	87%	Check-up	02/10/21 19h03	Melun	ME2	Amh...
SV3ZF7*****18	Model 3	86%	Check-up	02/10/21 19h07	Melun	ME2	Amh...
SV3ZU7*****98	Model 3	92%	Certificate	02/10/21 19h32	Melun	ME2	Amh...
KMHCCS*****62	Kona	100%	Check-up	02/10/21 19h37	Melun	ME2	Amh...
KMHCCS*****00	Kona	99%	Check-up	02/10/21 19h45	Nantes	team a	Anoryr
KMHCCS*****48	Kona	100%	Check-up	02/10/21 19h53	Nantes	team a	Anoryr
SV3ZU7*****98	Model 3	82%	Check-up	02/10/21 03h6	Nantes	team a	Anoryr
SINFAA*****76	Leaf	72%	Check-up	02/10/21 03h31	Nantes	team a	Anoryr
SINFAA*****00	Leaf	68%	Check-up	02/10/21 19h02	Melun	ME1	Léa J.

### Battery Check-up

27/05/2020

WORK SECURED BATTERY DOCUMENT REISSUE CODE  
WITH THIS IDENTIFICATION CODE:  
5098765797

RENAULT ZOE 41 KWH  
AA-123-BB  
INITIAL ENTRY INTO SERVICE: 20/09/2018  
MILEAGE: 57 000KM

#### Battery State

87%  
State of Health (SOH)\*

Number of BMS\*\* reprogrammations: 1  
Date of the last BMS reprogrammation: 20/02/2019  
Battery under warranty: Yes  
Remaining warranty: 6 years / 103 000km

#### Theoretical autonomy

SUMMER (25°C) WINTER (0°C)

Urban Cycle:	236-261 km	179-188 km
Highway Cycle:	162-179 km	140-154 km
Mixte Cycle:	198-219 km	163-180 km

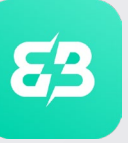
E3 For more information: [www.get-moba.com](http://www.get-moba.com)

**The simplest tool on the market to certify EV's batteries**



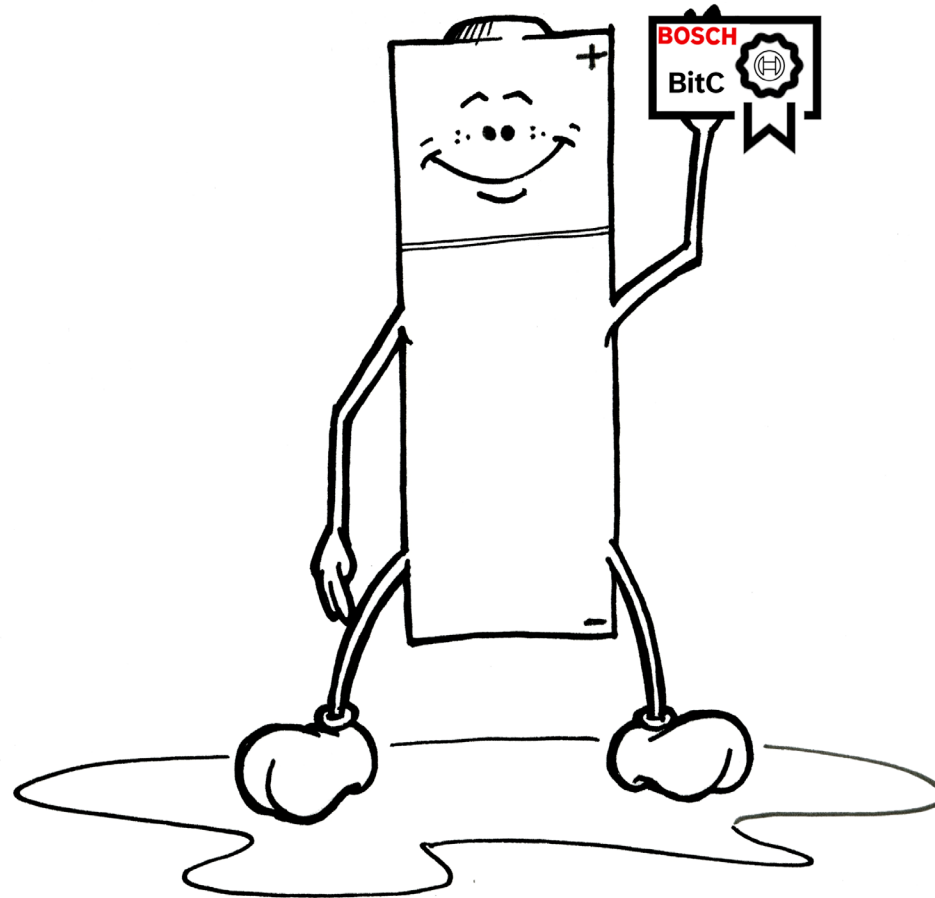
- **Easy & Fast to use**
- **Intuitive**
- **Without training**
- **Multi-brands**
- **+90% of BEV market covered**





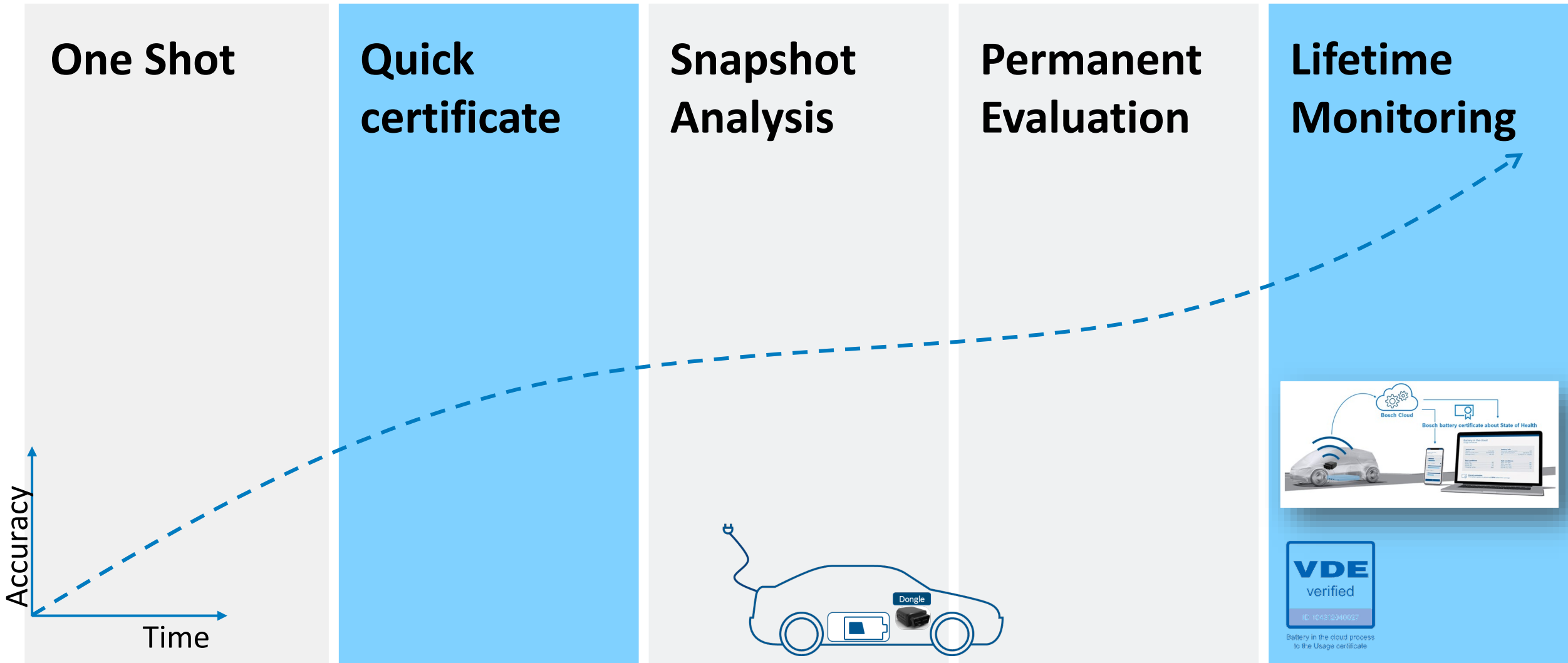
and more than 100 other companies in Europe...

# Bosch Battery in the Cloud



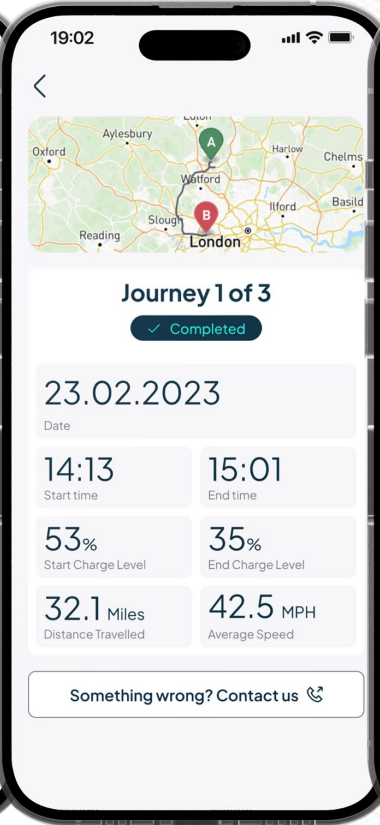
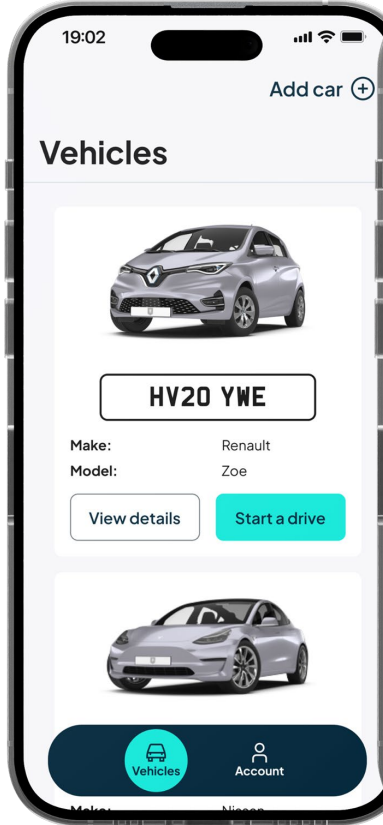
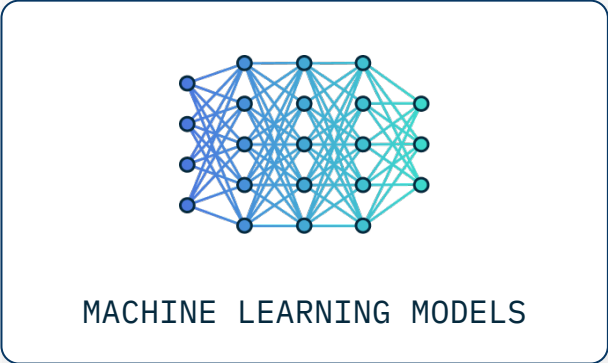
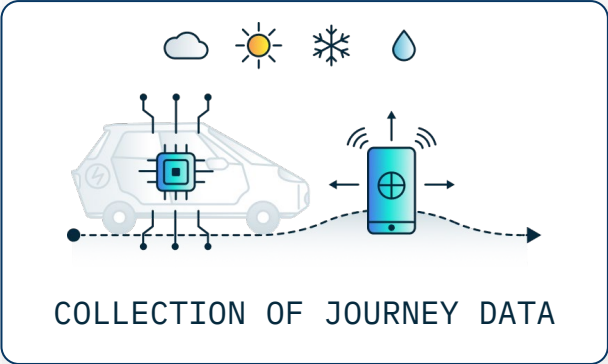
# Battery in the Cloud

## Usage Certificate



**Patrick Cresswell**  
**Managing Director**



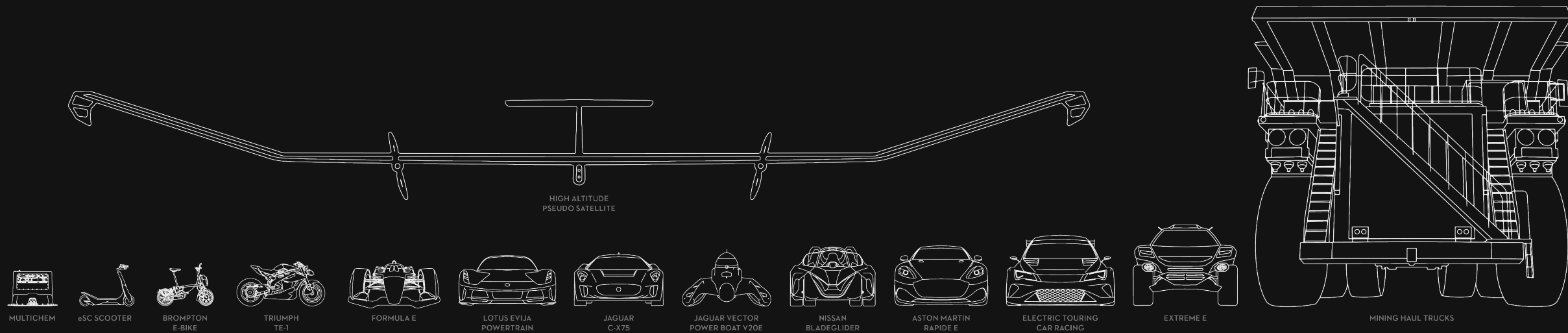




Early Prediction of Battery Remaining Useful Life Using Hardware Agnostic Software

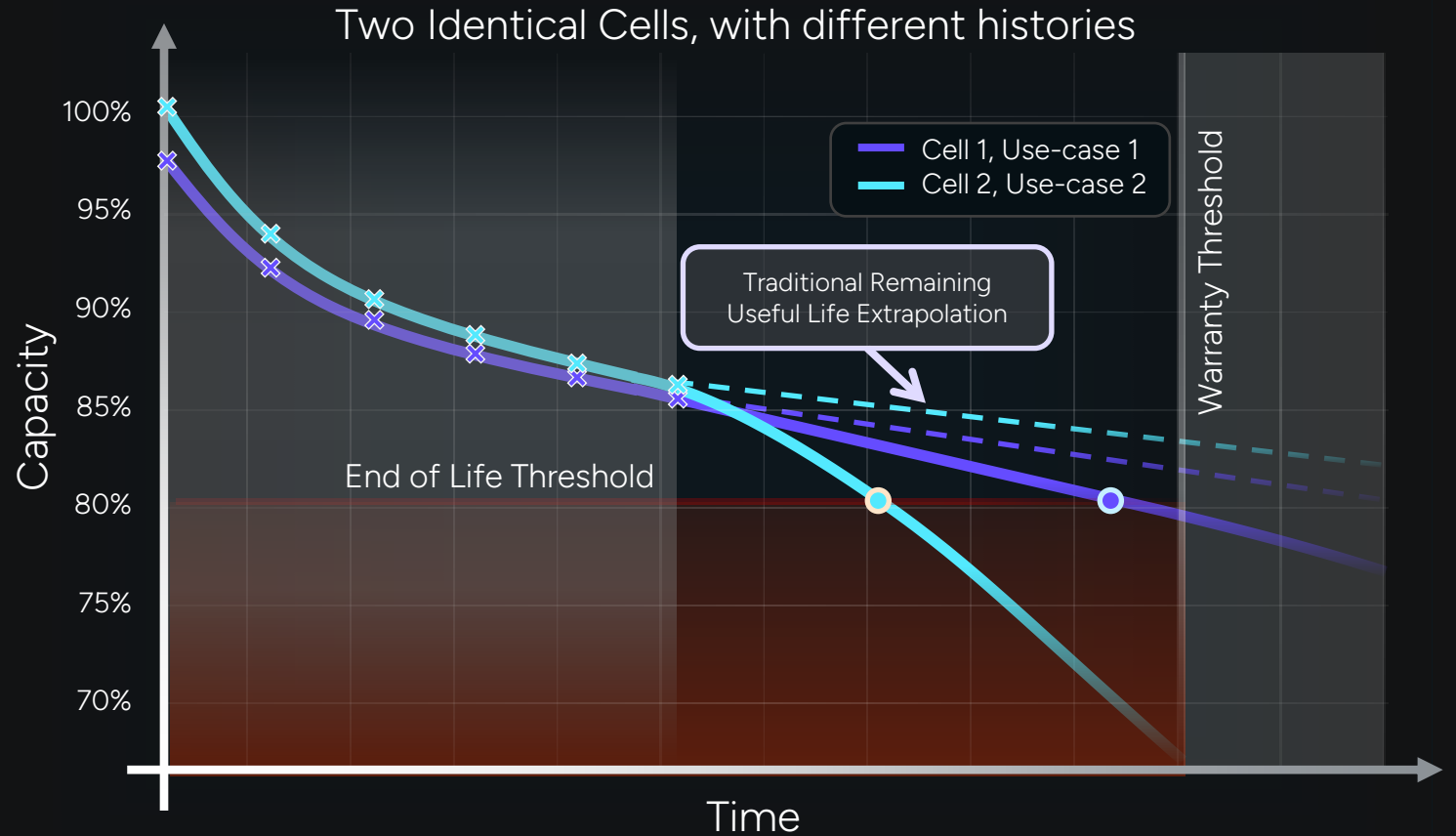
James Wallace – Product Lead

# 10 years of real-world electrification experience, rapidly innovating across industries, environments and technology paradigms

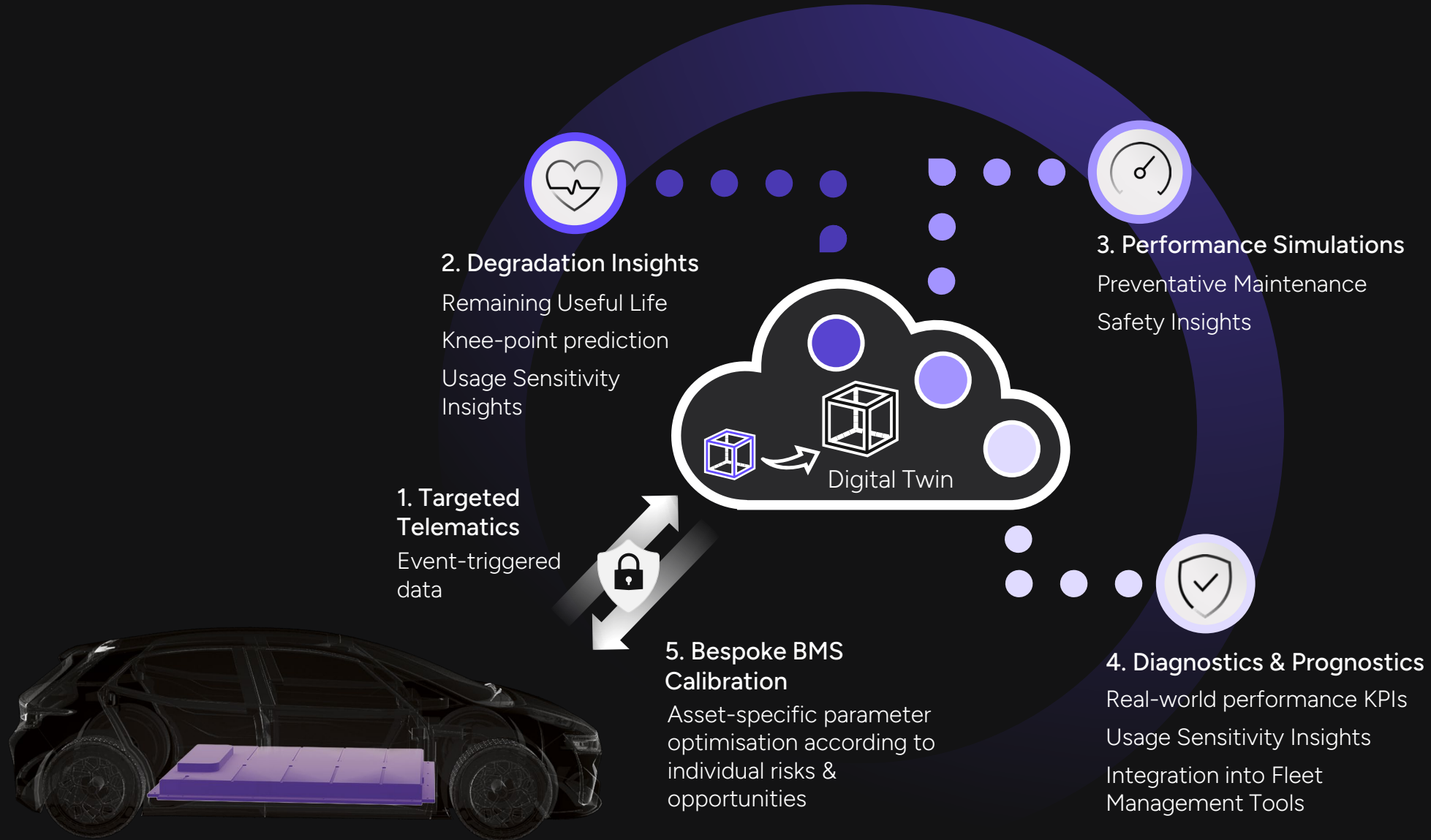


# Battery Lifetime potential is path dependent...

Two cells cycled to the same capacity may have very different prognoses, depending on **how** they got to this point (the use-case), even if they are treated equally from this point forward.









James Wallace  
Product Lead – Battery Intelligence  
james.wallace@wae.com

# Alex Johns

Business Development Manager

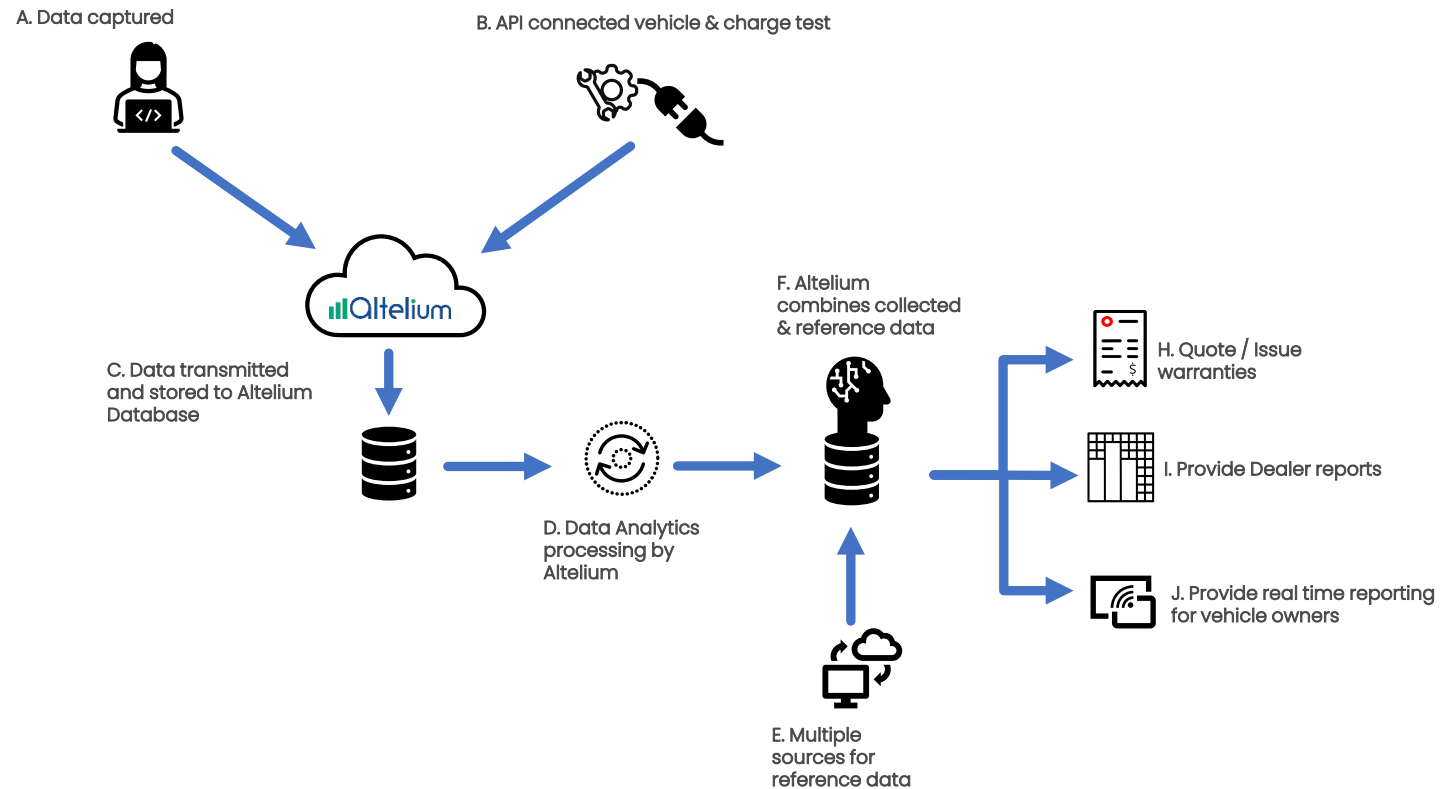


## The Value of Battery Health Certificates – The Altelium Practical Approach

# Methodology

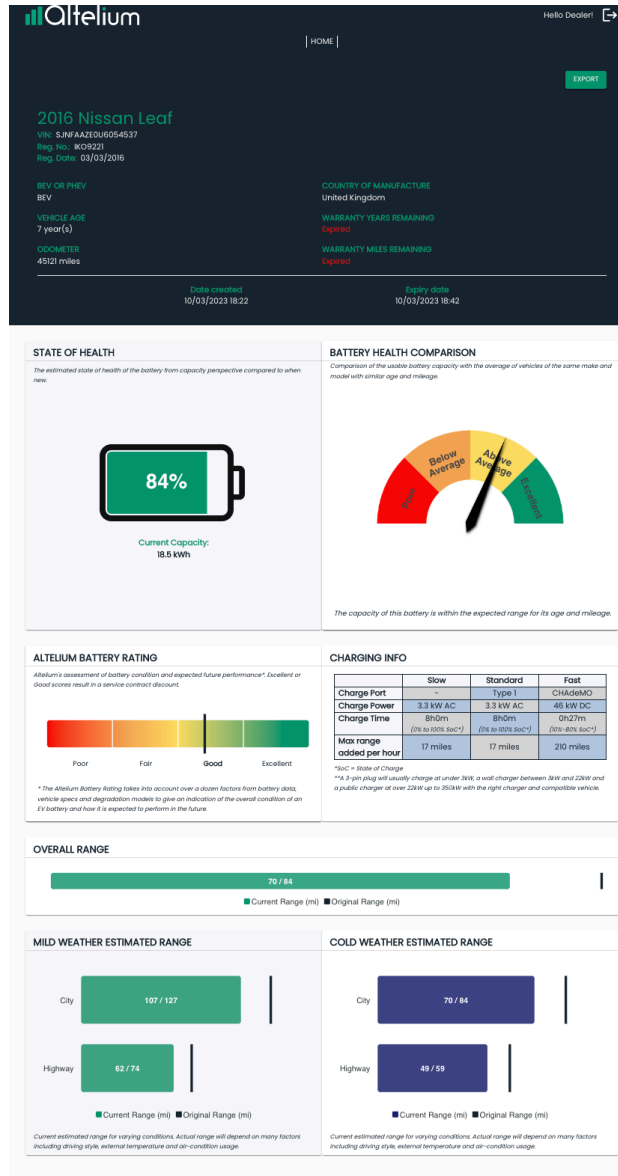
## Technology Overview

Our end-to-end tech platform enables the analysis of individual EV batteries on dealer forecourts, the provision of dealer reports and real-time reporting to vehicle owners.





# Dealer Report



# EV Insights



# We provide Dealer Extended Warranties, Dealer Reports and EV Insights

Altium provides EV Warranty solutions across the EV ecosystem for OEMs, Dealers, Leasing Companies, Fleets and Battery Cell OEMs. Our solutions include customer centric Dealer Reports and EV Insights for EV Drivers.

## EV OEM + Extended Warranty

**Product:** Battery data-driven OEM and Extended warranty

**Coverages:** Electrical and Mechanical Breakdown and Performance Breakdown (battery degradation risk)

**Client:** EV OEM / Dealer / fleet / leasing company

**Benefits:**

- Balance sheets protection
- Reduced buyer finance costs
- Increased buyer confidence
- Increased battery residual value

## EV Dealer Report + EV Insights

### EV Dealer Report

Benefit:

- Purchasing and pricing accuracy
- Ability to assess EV batteries
  - SoH and battery quality

### EV Insights for EV Owners as part of extended warranty

Benefit:

- Battery health reports
- Tips to prolong battery life
- Rewards program → Behavioural management

# Panel: Battery Health Certificates



Catherine Bowen  
BVRLA



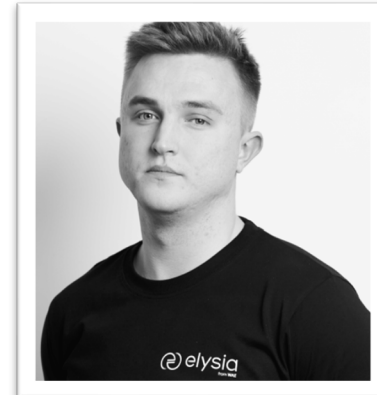
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# Final Thoughts

- Chair summary
- Thank you to Autotrader for supporting today's event
- Thank you to our speakers and you for participating in today's event
- **Feedback & Suggestions:** please spend a few minutes to complete the feedback survey when you receive the email