2pm – 3pm Thursday 30th June 2022

Theatre C Theme - Improving Battery Performance, Sustainability, Safety and Cost

Can We Achieve Ultra Fast Charging *and* Optimal Performance Conditions Using Better Thermal Management?
Safety, cell aging and performance are just a few of the reasons that good thermal management is crucial to H/EV success - but the pressing and growing need for ever faster charging is raising the stakes even further. Fast or ultra fast charging is seen by many as crucial in attracting those consumers seeking to replicate their ICE user experience. A cohesive thermal management system can be the difference between maintaining a healthy, long lasting battery and running the risk of thermal runaway or extreme degradation, with well publicised results.

This session will consider current thermal management best practice, before considering the extra burden from fast or ultra charging and finally our panel of experts will discuss what the options are for maintaining optimal thermal range at all times.

Housekeeping points

- Mobiles on silent and vibrate mode off.
- Flash photography and taking photos of slides is prohibited.
- Presentations that the organisers have authorisation to share, will be made available to view/ download, via the event websites, post event.
- Please utilise the event app for conference questions, you will find guidance on how to do this in the conference pages of the show guide (Page 10).
- There will be microphones in the aisles for Q&A.

Panel speakers: Dr. Yu Merla

Talk: Can We Achieve Ultra Fast Charging and Optimal Performance Conditions Using Better Thermal Management?

Principal Engineer, Advanced Battery Projects,
Williams Advanced Engineering (WAE)

- After completing his Master's in Mechanical Engineering, Yu went on to achieve a PhD in Lithium-Ion cell technology from Imperial College London.
- His work here, on life-extending battery prognosis algorithms caught the attention of WAE, where he became involved in the first-generation Formula E battery.
- Since then, he has been involved in a number of high performance automotive and aerospace projects including for the likes of Airbus, Lotus, Aston Martin and many more.
- Yu now leads the team within WAE, looking at battery modelling, advanced algorithms and performance optimisation for major projects.

Panel speakers: Dr. Guillaume Gerbaut

Technical Sales Manager, Low Voltage Business Line, Von Roll

- 15 years of experience in research & development resin field
- Strong skills in Polyurethane & Epoxy Potting resins
- Since 2020, moved to Application Engineering team to provide low voltage solutions & adapted processes to customer

Panel speakers: Dr. Winfried Koch

Managing Director, CSM

- Winfried completed his doctoral thesis on control at the University of Stuttgart. Together with his wife, Iris - an electrical engineer, he founded CSM GmbH in 1986.
- CSM is a leading company for very compact, robust and power saving measurement hardware and systems with worldwide activities and Vector Informatik GmbH as partner.
- CSM today focuses on supporting its customers with their transition to E-Mobility.
- For analysis, test and validation of HV Batteries and complete electrical Powertrains, CSM has developed tailor-made solutions for precise, multi-channel temperature measurement as well as for HV safe measurement of current, voltage, pressure, strain and vibration.

Imperial College London

ELECTROCHEMICAL SCIENCE & ENGINEERING

THE FARADAY INSTITUTION

MULTI-SCALE MODELLING

Modelling

Thermal Management

An effective way to make batteries perform better and last longer

Dr. Jacqueline Edge

Imperial College London and The Faraday Institution

How do we make better batteries?

Faraday Institution targets

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

1st 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)

Adapted from content from Professor Dave Greenwood at Warwick Manufacturing Group

Why is thermal management so important?

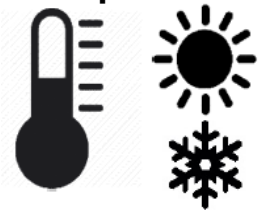
Energy density

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)

Temperature



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

Improves performance:

- higher temperatures means more mobility of ions
- extends operating temperatures
- Increases efficiency by up to 20 %

1st life

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

Limits degradation -> extends lifetime:

- reduces total cost of ownership
- extends warranties
- improves sustainability

Safety

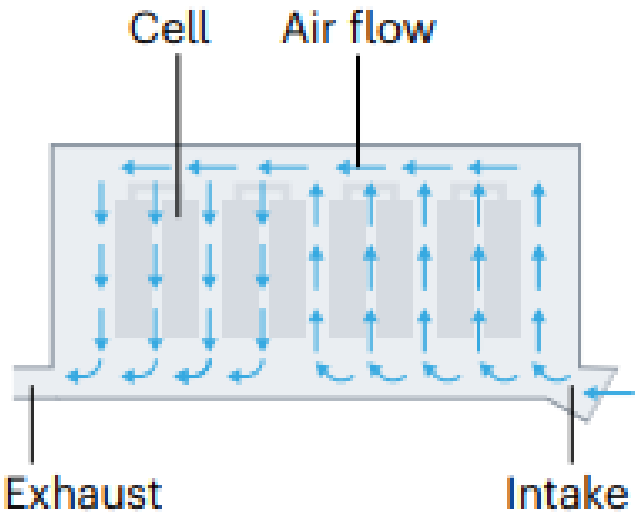
Future eliminate thermal runaway at pack level to reduce pack complexity

Improves safety:

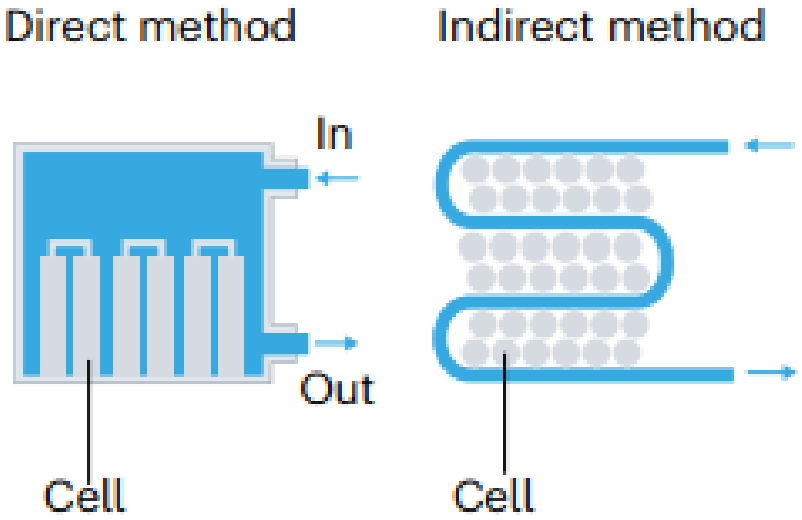
- mitigates thermal runaway (positive feedback loop causing uncontrolled heating >10 °C/minute)

Battery thermal management systems

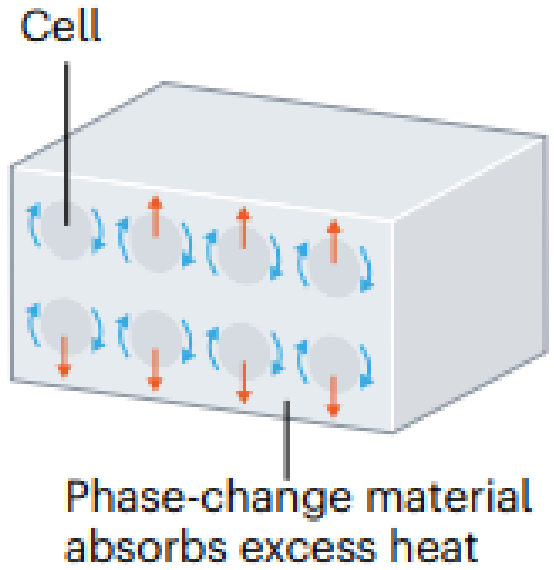
Air
Cheap, low power demand, poor performance



Liquid
Expensive, high power demand, good performance

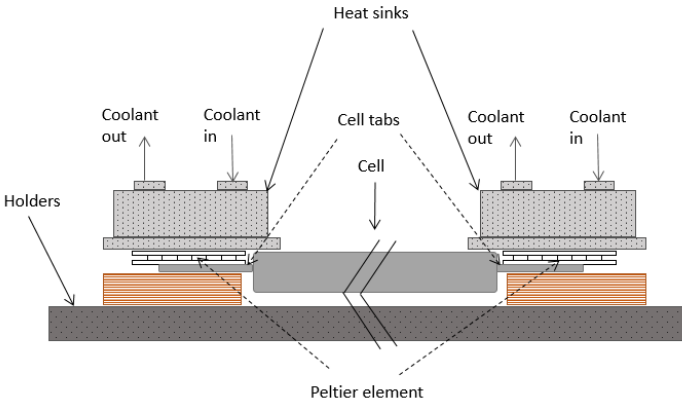


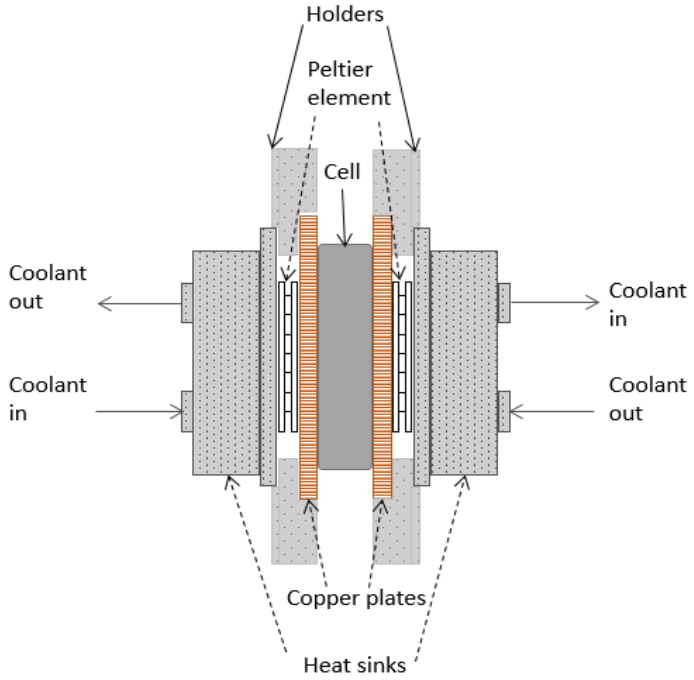
Phase change
Expensive, requires extra cooling systems, unproven performance

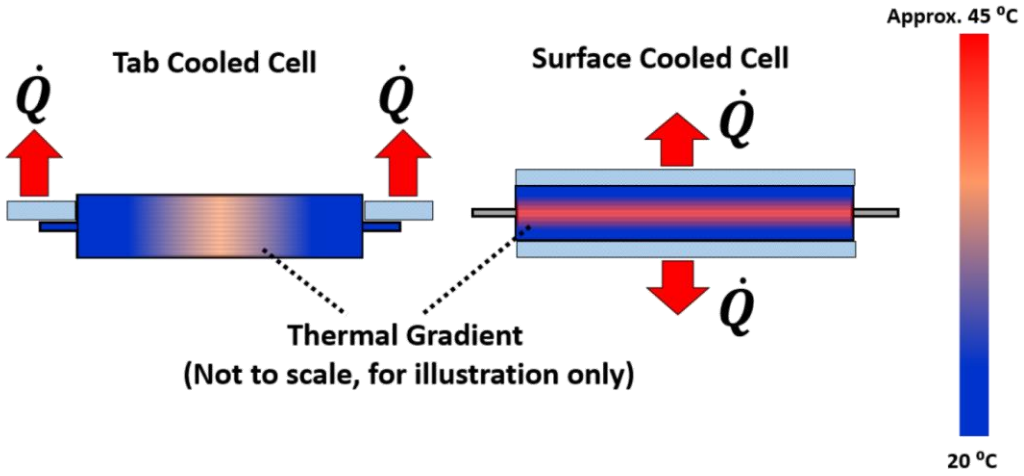


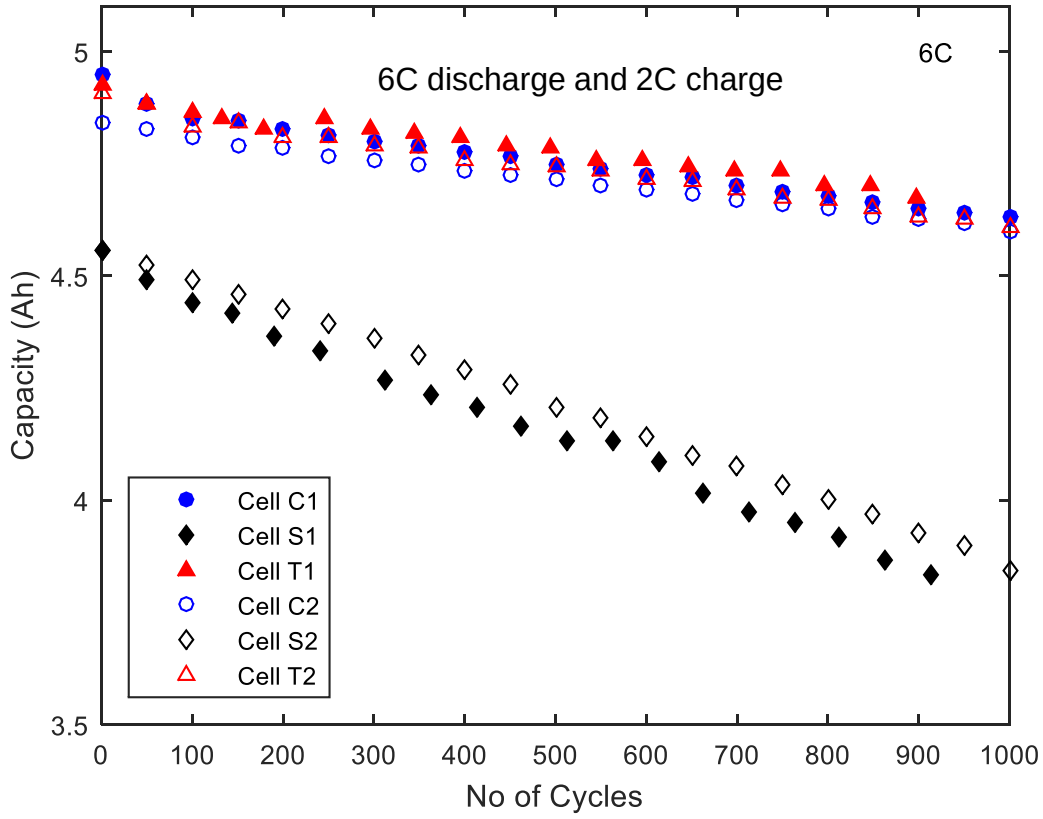
Cool metric for lithium-ion batteries could spur progress. Offer et al. Nature 2020

The importance of homogeneity: surface vs tab





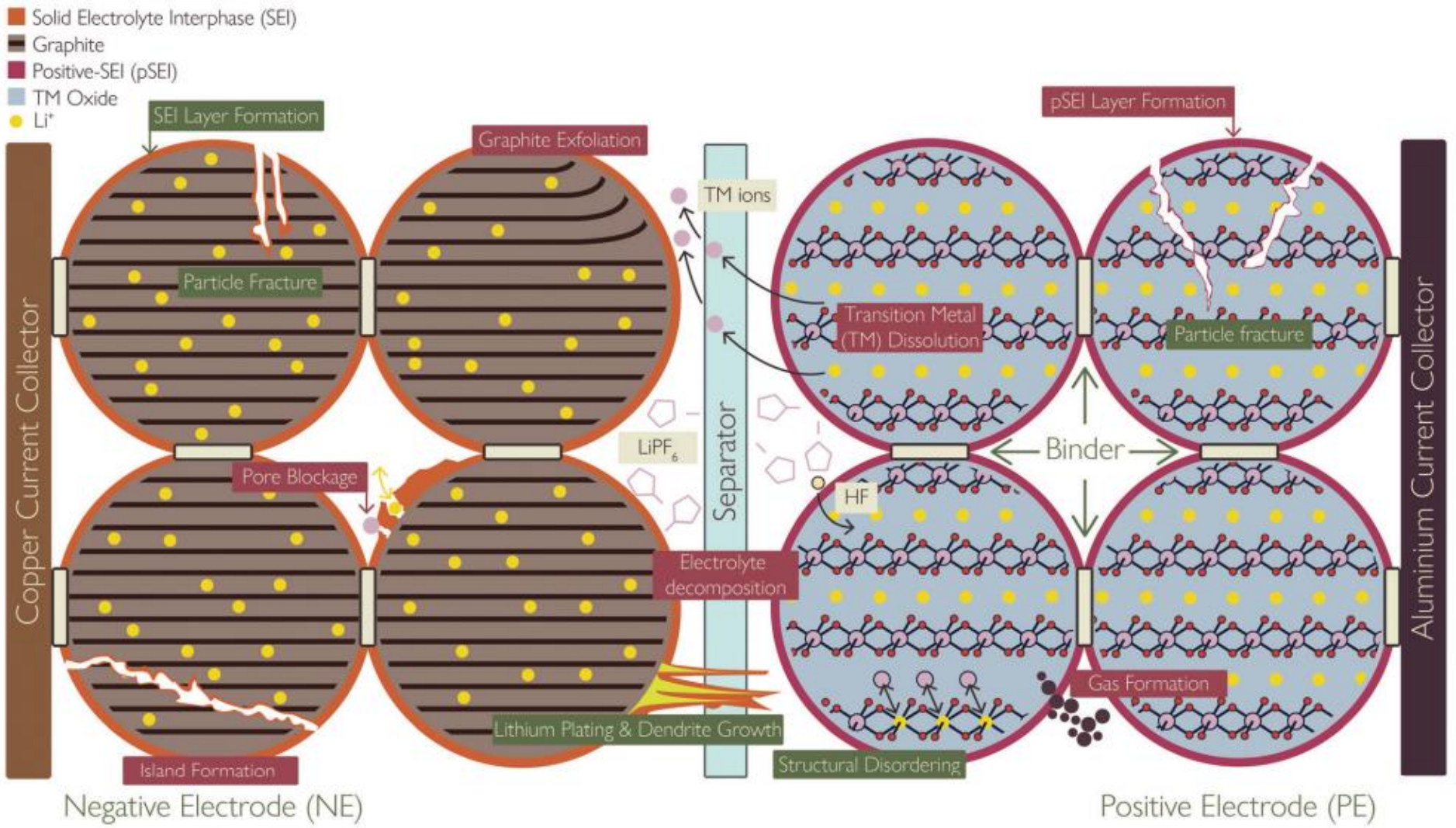




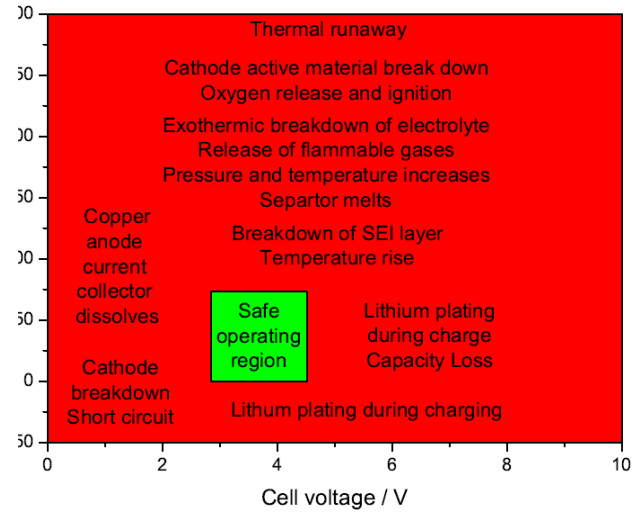
Tab cooling is evidenced to outperform other thermal management methods, when the cell is designed correctly

Surface Cooling Causes Accelerated Degradation Compared to Tab Cooling for Lithium-Ion Pouch Cells. Hunt et al. Journal of the Electrochemical Society. 2016,

Degradation in lithium-ion batteries



Many mechanisms:



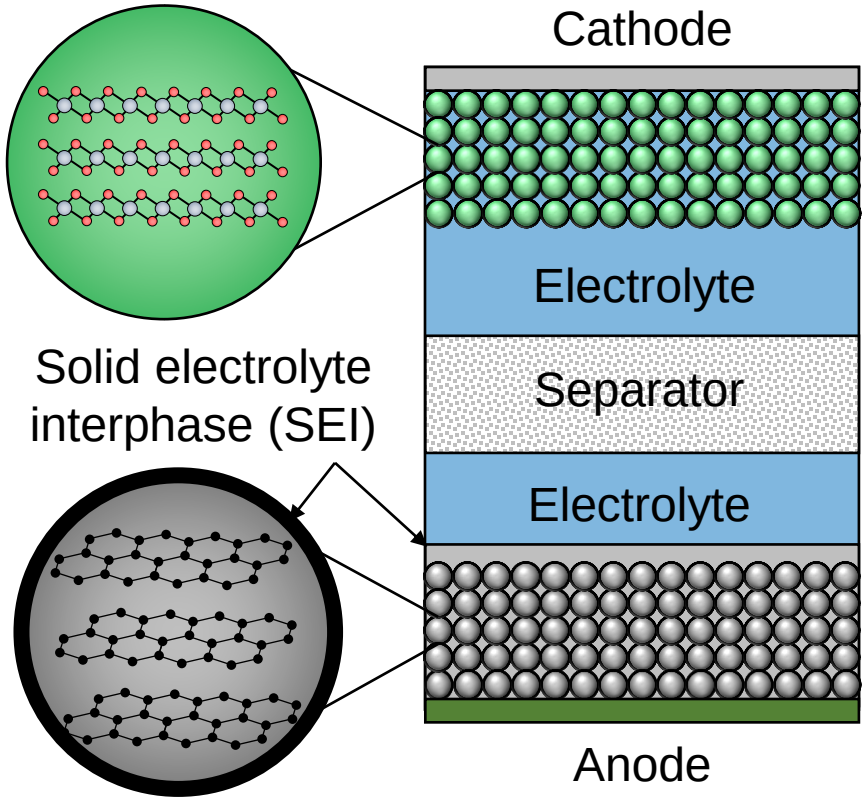
Lithium-ion battery degradation: What you need to know. Edge et al. PCCP. 2021

Most processes exacerbated by temperature (low or high)

Safety

Eliminate thermal runaway

What happens when lithium-ion batteries go wrong?



Thermal runaway

Heat accumulation

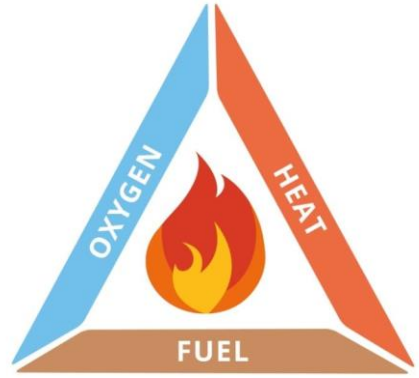
Cathode decomposition	300°C
Electrolyte decomposition	200°C
Separator melting	130°C
Electrolyte + anode reaction	100°C
SEI decomposition	70°C

Oxygen release

Hydrofluoric acid release

Internal short circuit

Heat production



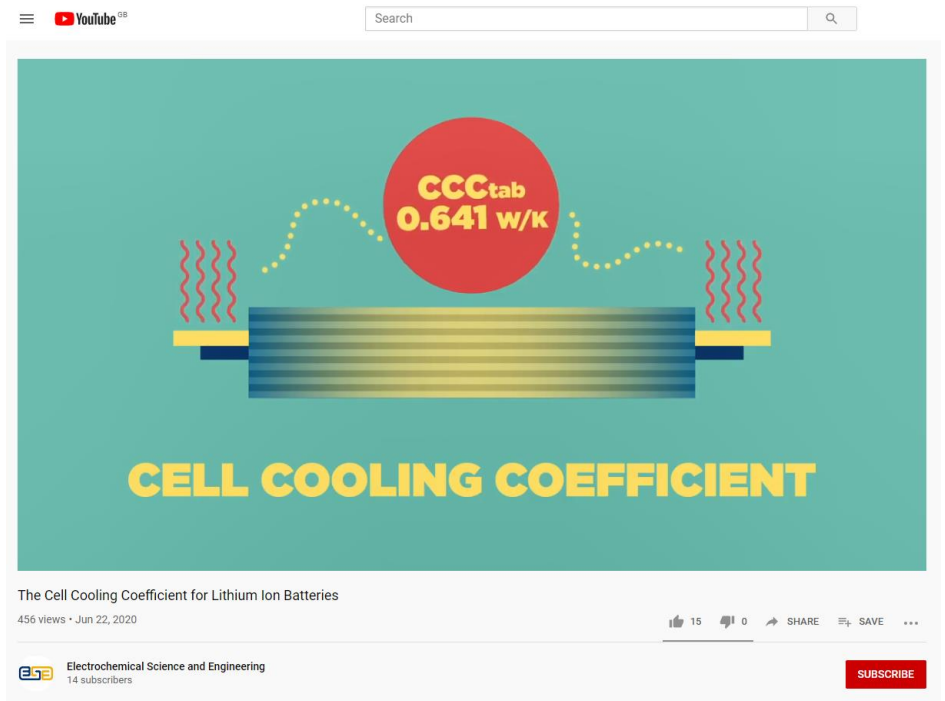
Common battery electrolyte components = Salt + solvent
Salt = Lithium Hexafluorophosphate ($LiPF_6$)
Solvent = Ethylene Carbonate (EC), Dimethyl Carbonate (DMC)

Adapted from Progress of enhancing the safety of lithium ion battery from the electrolyte aspect. Wang et al. Nano Energy 2018; 55 :93–114 .

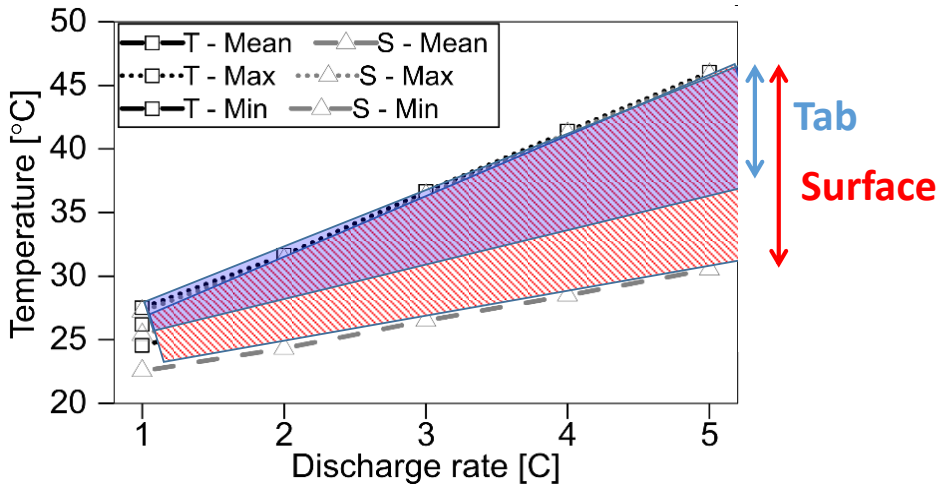
Designing cells for thermal management: the Cell Cooling Coefficient

1. The CCC is a Standard to compare the thermal 'performance' of any battery[1]
2. A simple empirical measurement of how easy it is to reject heat in $W.K^{-1}$
3. It is a fundamental lumped property of the device, independent of how it is used
4. The goal is to change the way the global industry thinks, and through comparison trigger competition to design better cells

https://youtu.be/mIihRRq7LgU
https://www.iqiyi.com/v_19rzczvce8.html



Virtual LG Chem E63 cell redesign study, predicted increased cooling rates, extended performance & lifetime[1]



[1] Hales, A. *et al. Journal of the Electrochemical Society*, Vol 166, A2383–A2395 (2019).
[2] Zhao, Y. *et al*. *Journal of the Electrochemical Society*, Vol 166, Pages A2849-A2859 (2019)
[3] Offer, Gregory J. *et al. Nature* 582, 485-487 (2020) doi: 10.1038/d41586-020-01813-8

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1st life

Future 15 years (pack)

Extending first life

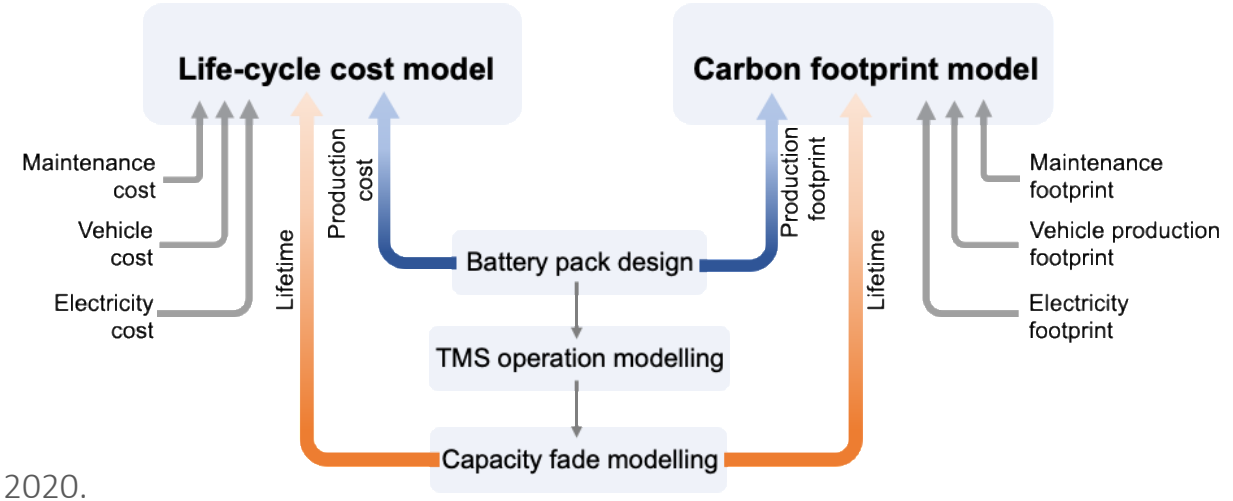
THE FARADAY INSTITUTION MULTI-SCALE MODELLING Modelling

Research questions:

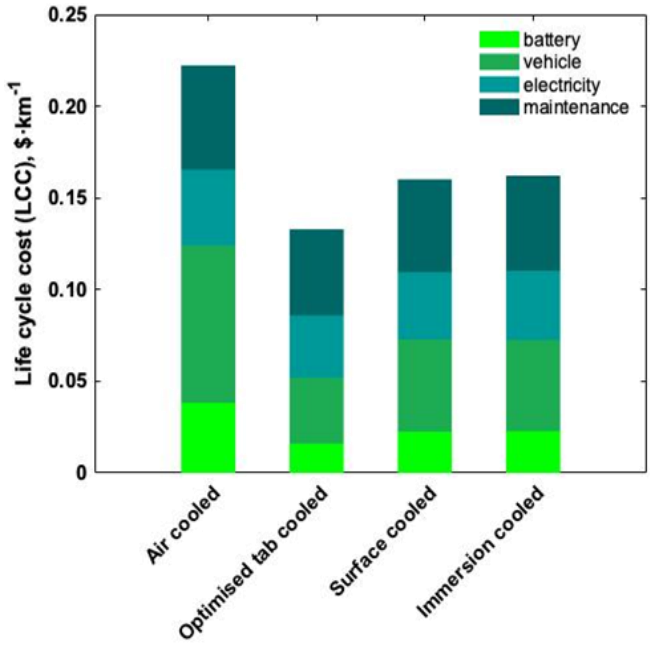
- Can thermal management improve lifecycle cost and carbon footprint?
- Which thermal management system is the best?

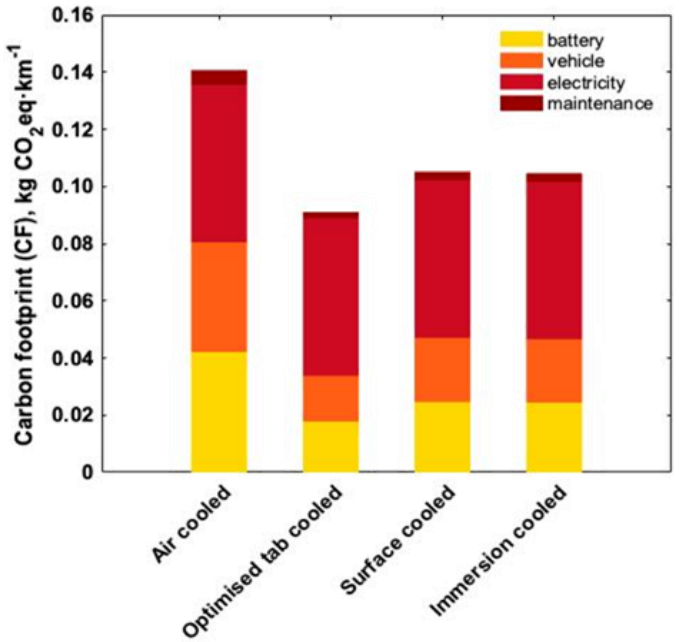
Outcome:

- **Optimised tab cooling*** leads to longest battery cycle lifetime and thus lowest lifecycle cost (27 % reduction) and carbon footprint, compared to other cooling methods



* G. Offer *et al. Nature 582,* 2020.





Dr. Laura Lander
Imperial College London

Cost and carbon footprint reduction of EV LIBs through efficient thermal management

Lander *et al. Applied Energy* **289** (2021) (10.1016/j.apenergy.2021.116737)

Impact of fast and ultra-fast charging

- Typical charger (22 kW AC) provides enough charge in 120 minutes for 200 km
- To reduce this to 16 minutes, we need high C-rate charging (150 kW AC)
- The temperature can increase to over 270 °C in ten minutes
- Aggressive thermal management required
- Main degradation mechanisms:
  - Lithium plating – usually occurs at low temperatures, but will also occur at high temperatures
  - Solid-Electrolyte Interphase (SEI) layer growth
- Heating & cooling required to maintain 15–35 °C
- Current TM systems not sufficient: needs cell redesign as well