LiFETIME+ Final Presentation

Enabling second-life battery production.

UNIVERSITY OF CAMBRIDGE

Centre for Global Equality

SENSOR CDT

UKRI Engineering and Physical Sciences Research Council

Image from Nano Magazine - https://nano-magazine.com/news/2018/6/13/the-technologies-which-are-revolutionizing-batteriesc

The iOS family pile (2015) - Blake Patterson via flickr. Licenced under Creative Commons By 2.0 Deed

Landfill

Recycling

Image by Ashley Felton - Public Domain

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Image from The New Economy: [Schneider Electric is helping to bring reliable electricity to Africa]

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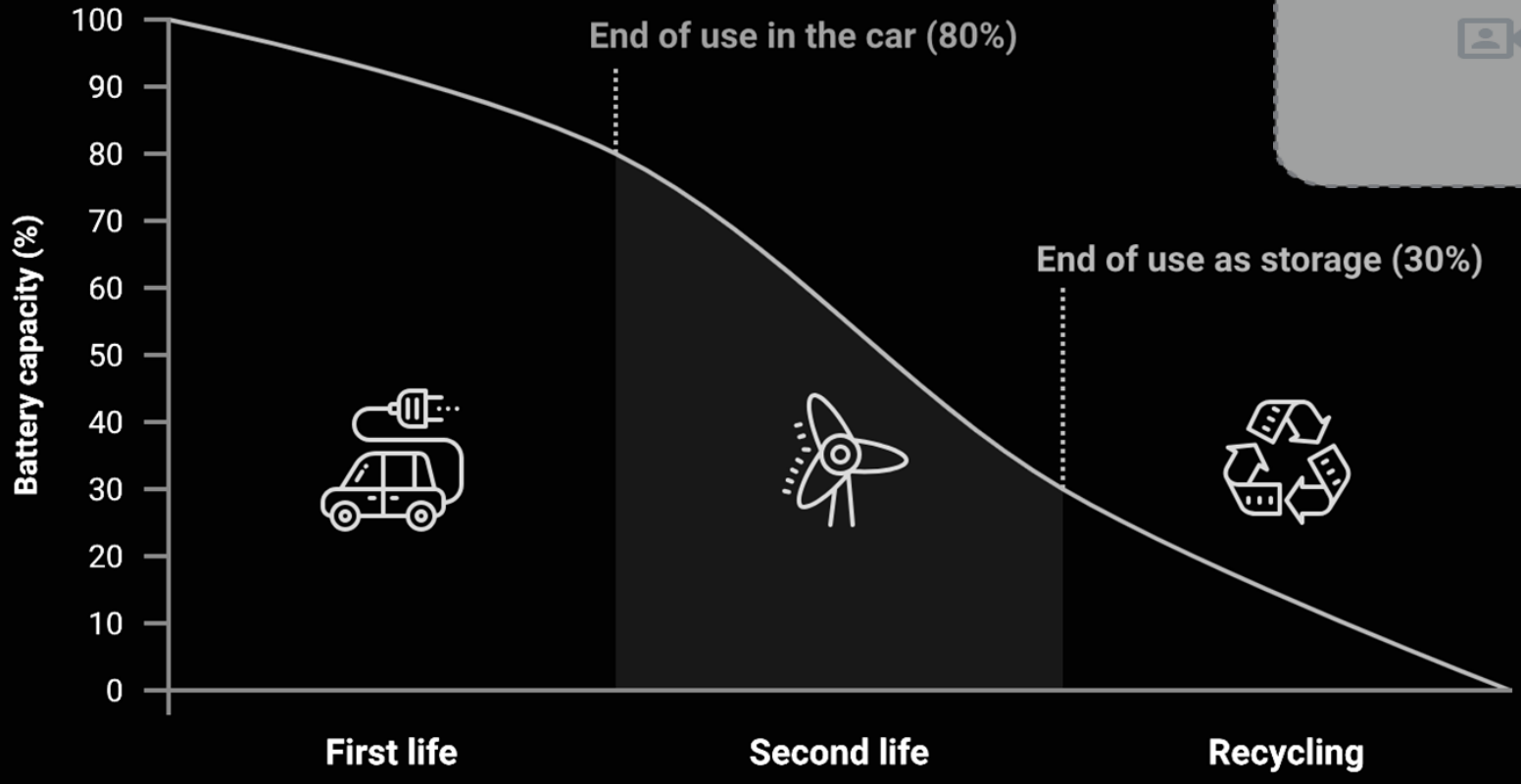


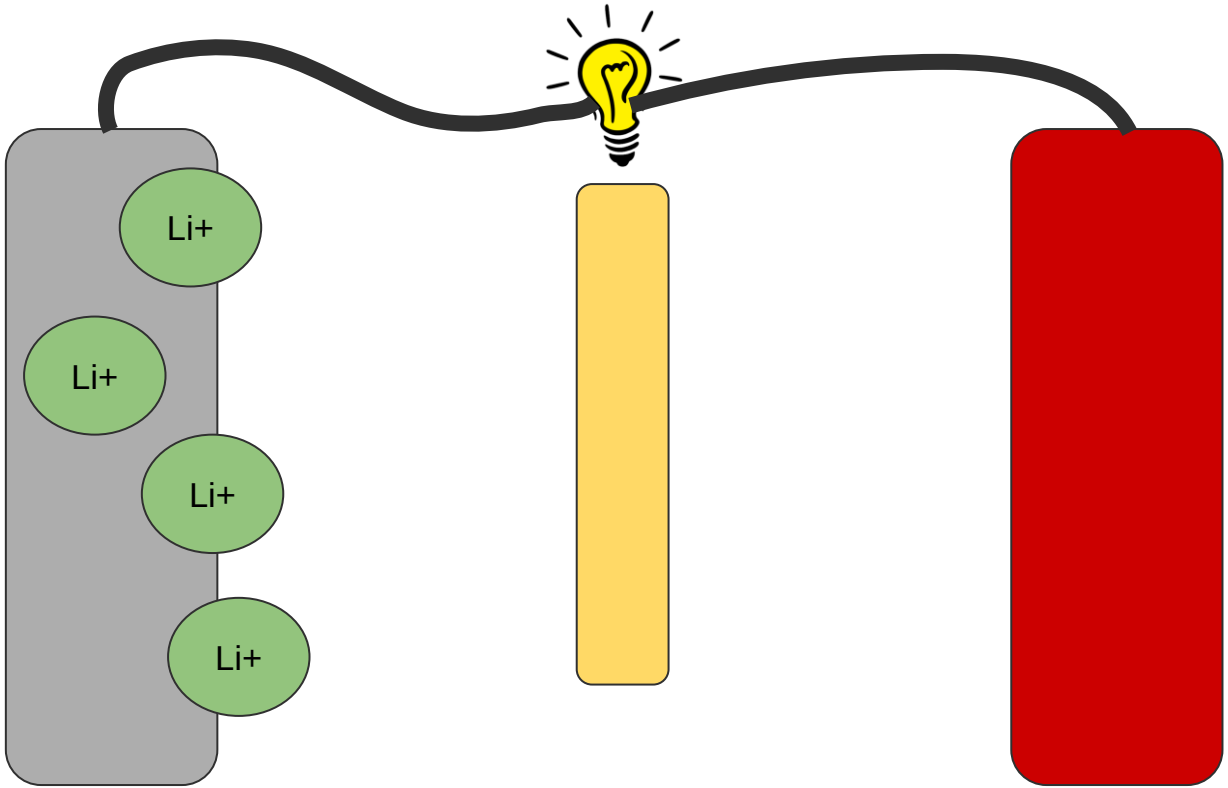
Adapted from Drax.com

7
AFFORDABLE AND
CLEAN ENERGY

11
SUSTAINABLE CITIES
AND COMMUNITIES

12
RESPONSIBLE
CONSUMPTION
AND PRODUCTION

What is a Li-ion Battery?



The Strategy of Achieving Flexibility in Materials and Configuration of Flexible Lithium-Ion Batteries - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Schematic-diagram-of-working-mechanism-of-lithium-ion-battery_fig1_356134415 [accessed 3 Jun, 2024]

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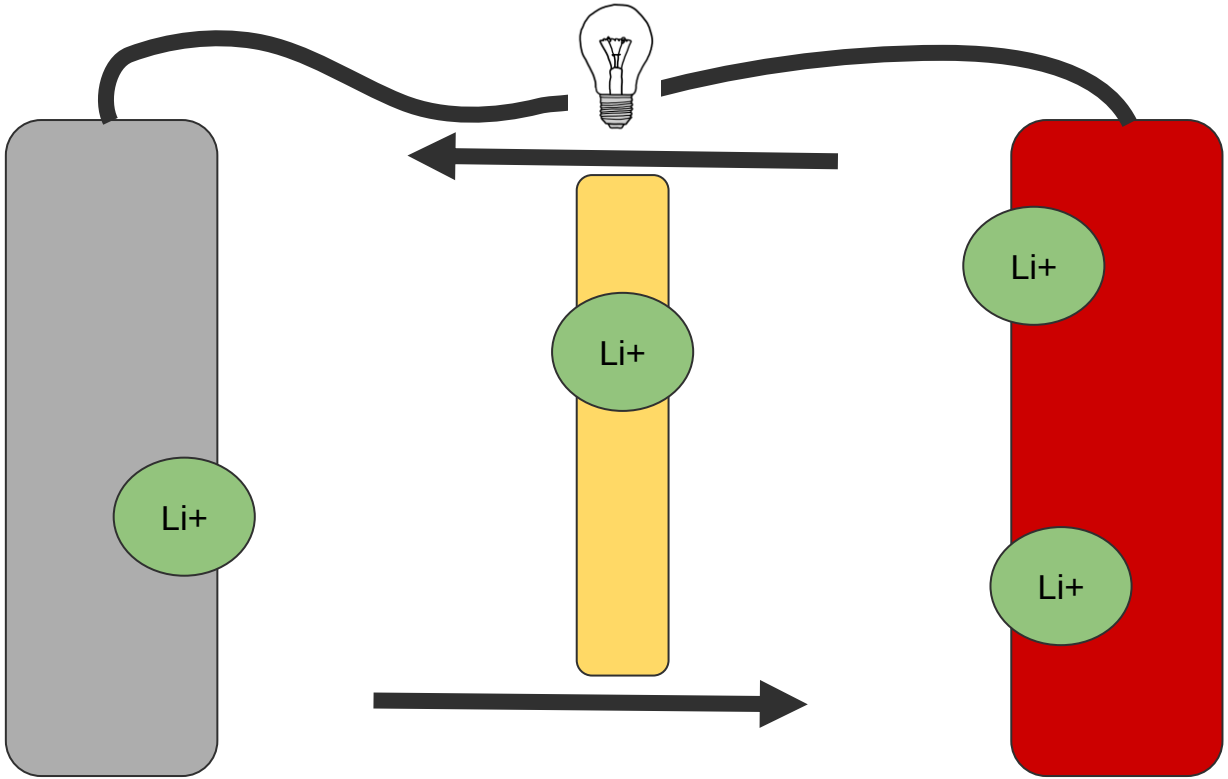

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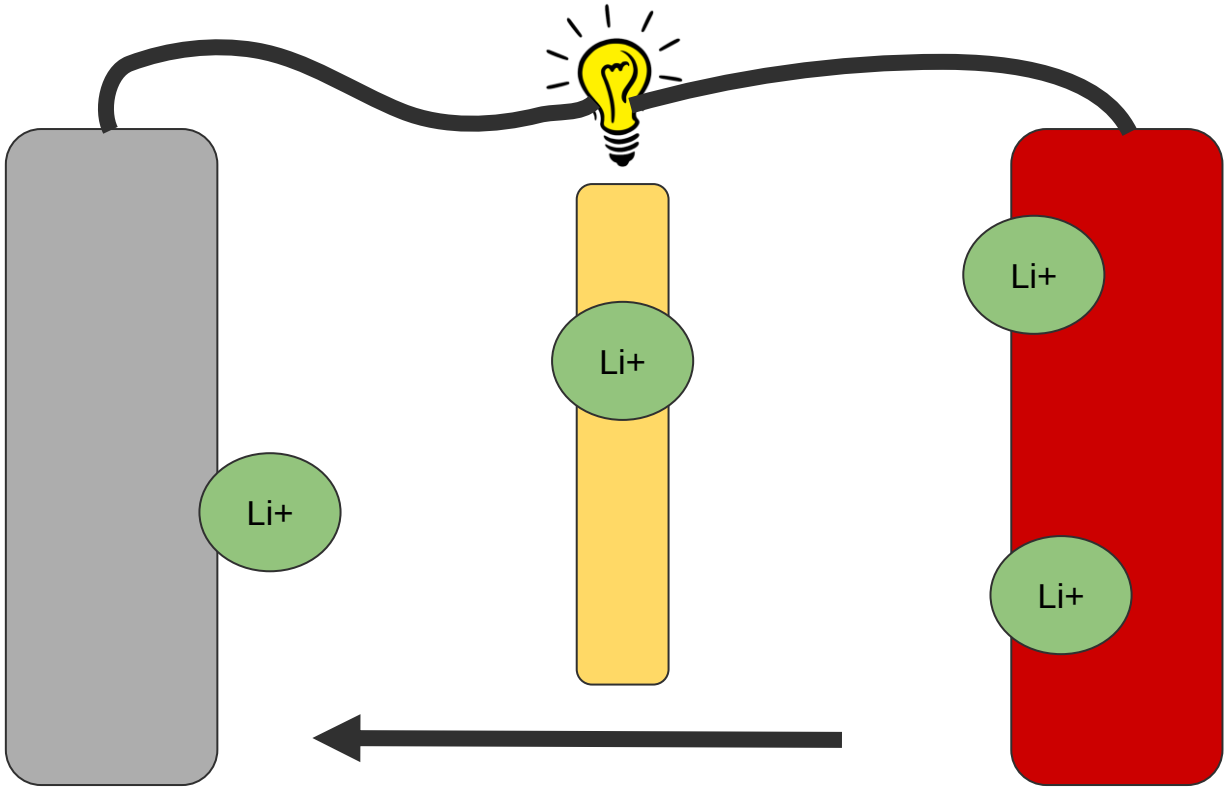

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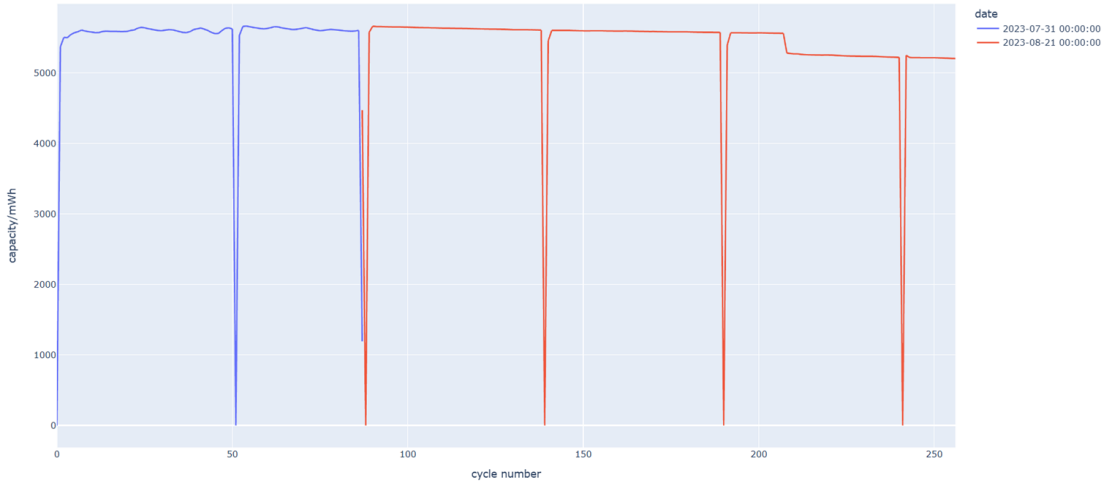
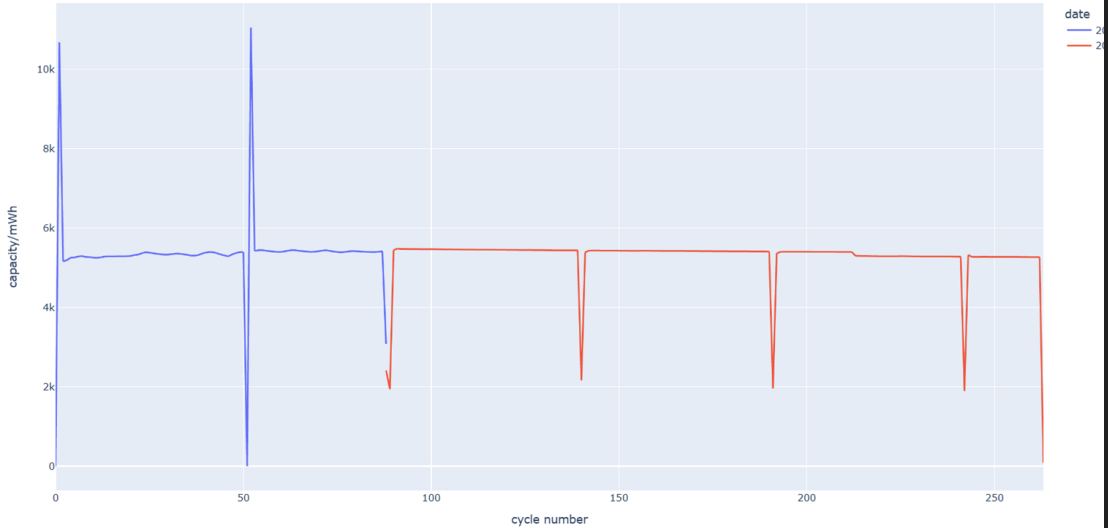
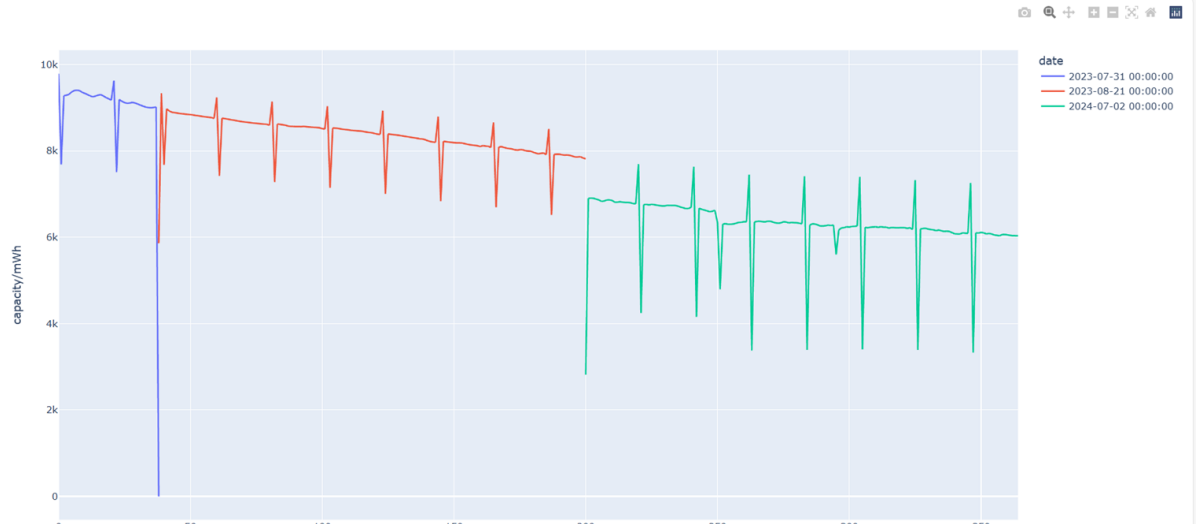
Image from eBay

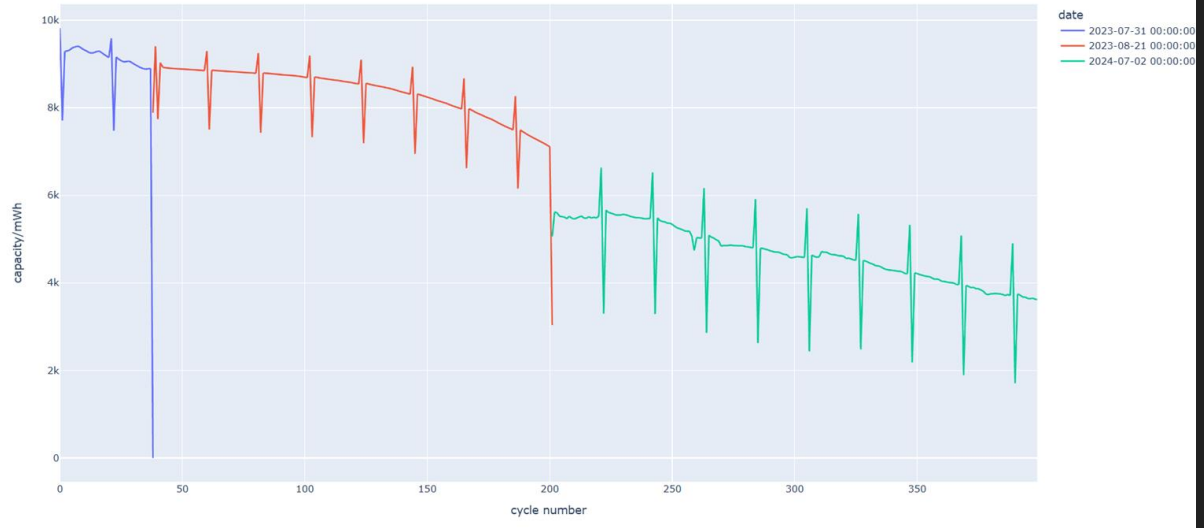




Lithium-Phosphate

- Used in energy storage and off-grid living.
- Low capacity loss over time.
- Heavier, Larger.

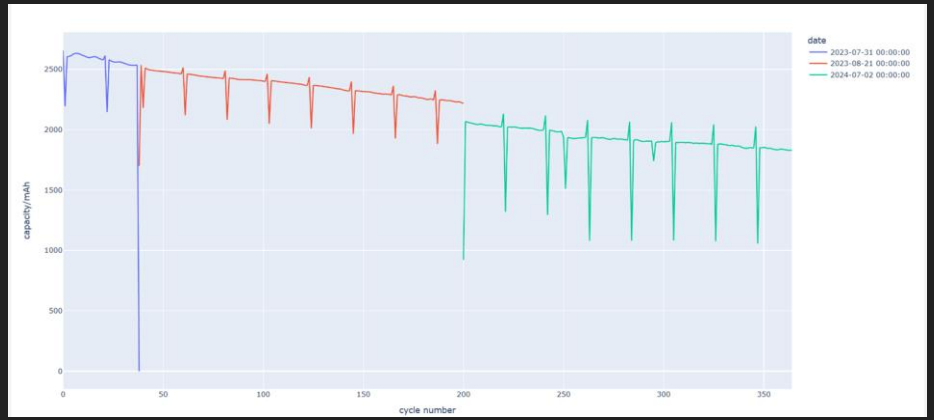




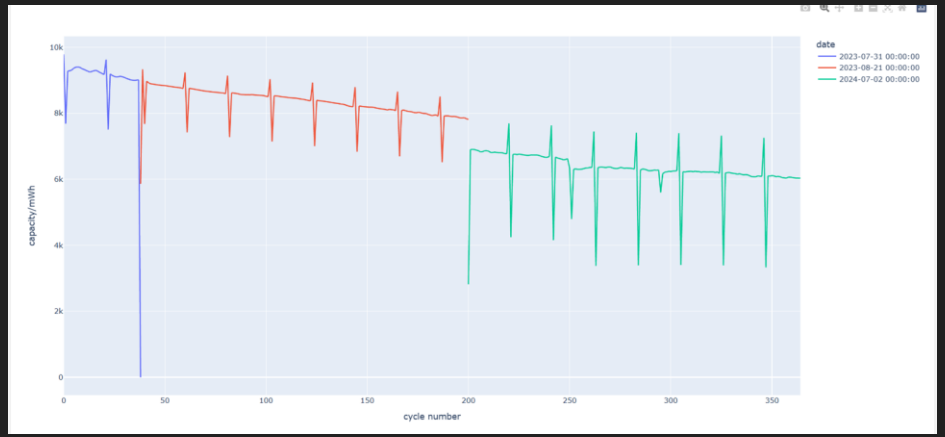
Lithium-Cobalt

- Used in portable applications (phones, tablets, cars)
- High capacity loss.
- Lighter, smaller.

Power = Voltage x Current



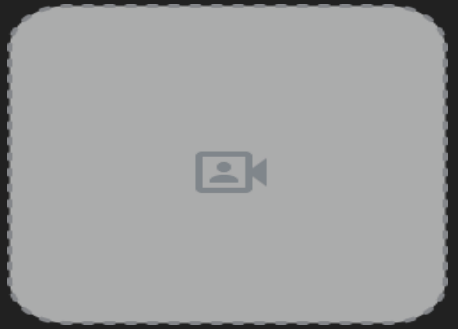
Capacity (mWh)



Capacity (mAh)

The problems with predicting battery health.

- Cycling data is expensive
- Degradation depends on:
  - Charging and Discharging (Speed, Depth)
  - Temperature
  - Cell chemistry
  - Time spent charged.
- Future life application depends on the process which degraded.

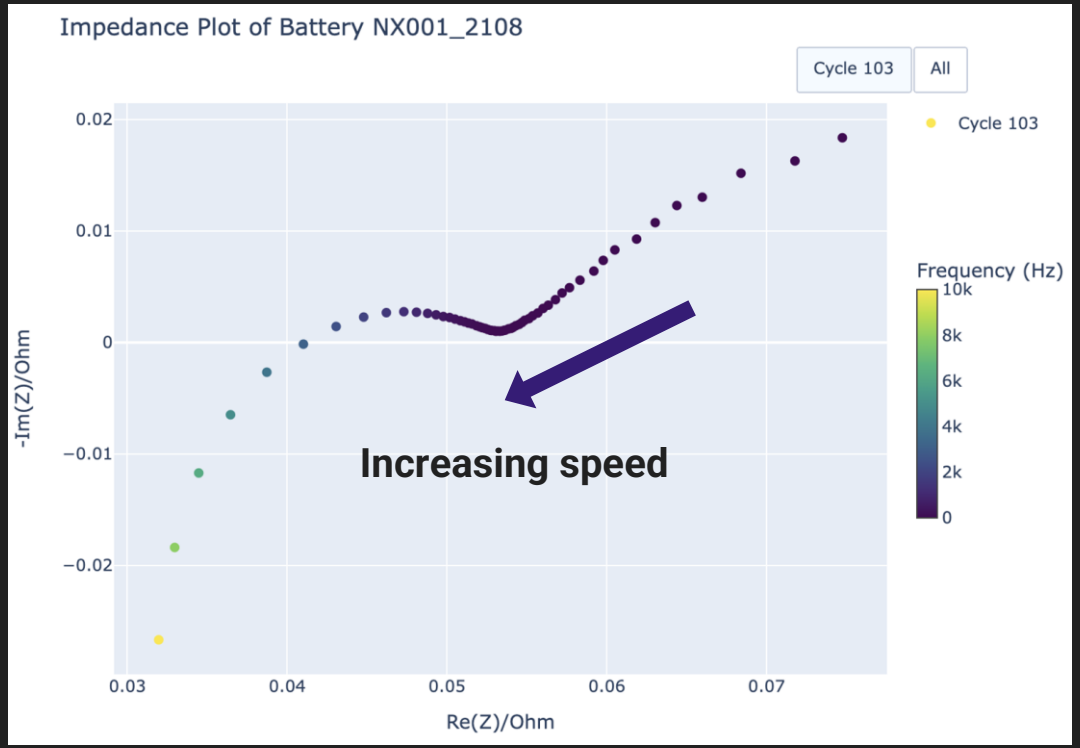


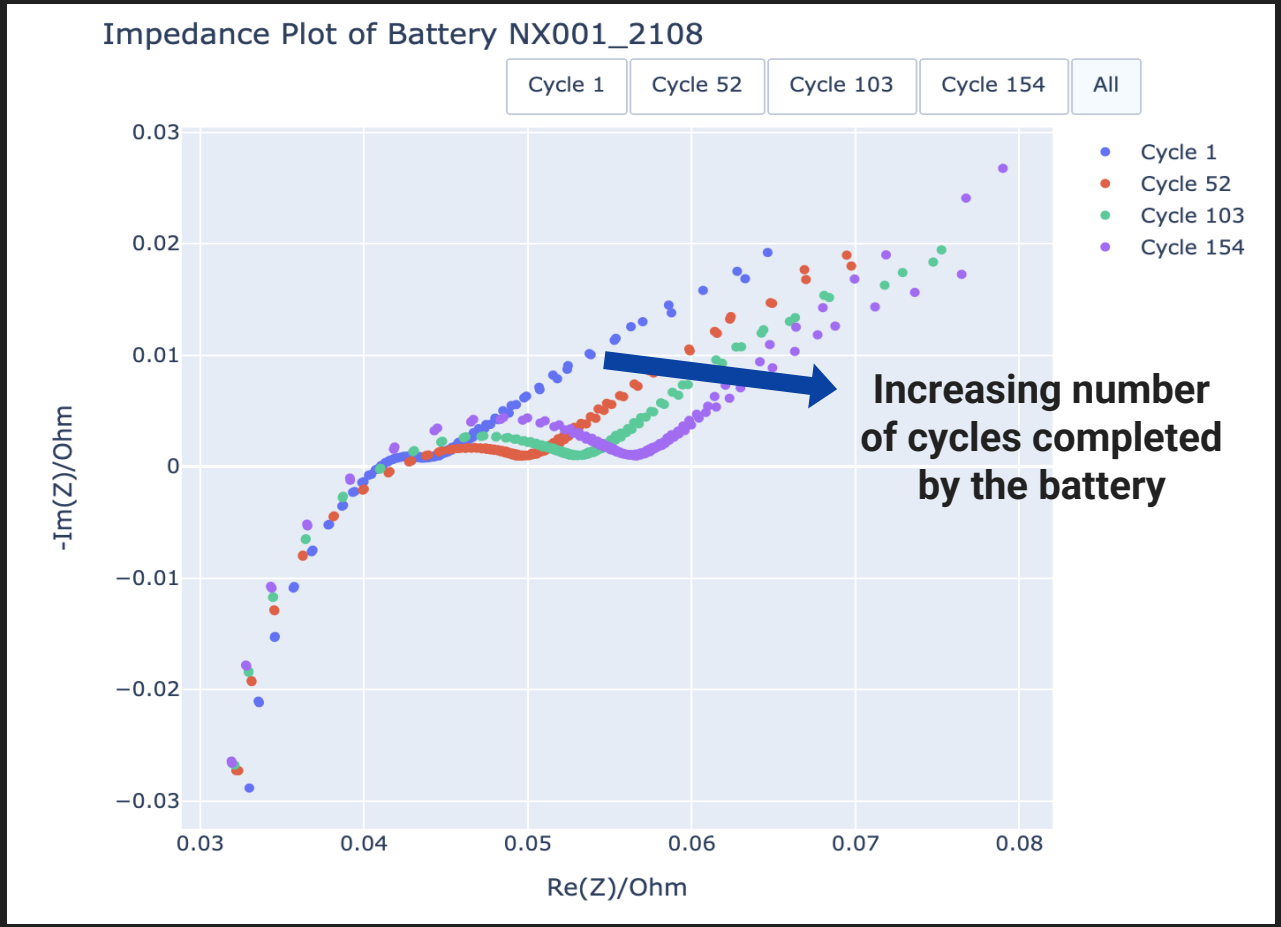
EIS: A different approach

EIS Testing Equipment

EIS = Electrochemical Impedance Spectroscopy

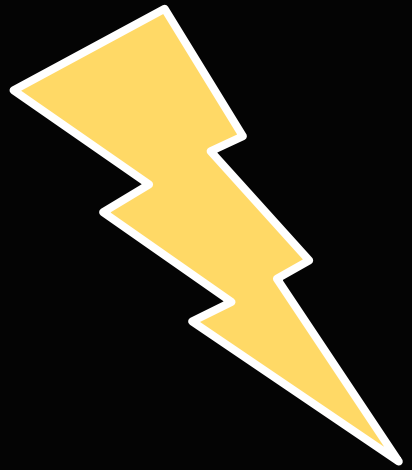
An example of an EIS spectrum




Impedance Plot of Battery NX001_2108
Cycle 1
Cycle 52
Cycle 103
Cycle 154
All
0.03
0.02
0.01
0
−0.01
−0.02
−0.03
-Im(Z)/Ohm
0.03
0.04
0.05
0.06
0.07
0.08
Re(Z)/Ohm
Cycle 1
Cycle 52
Cycle 103
Cycle 154
Increasing number of cycles completed by the battery

Why is EIS useful?

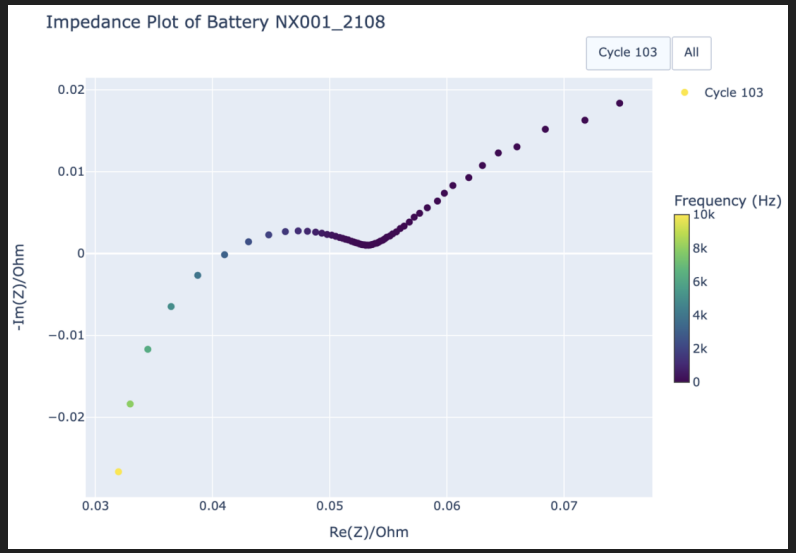
Time

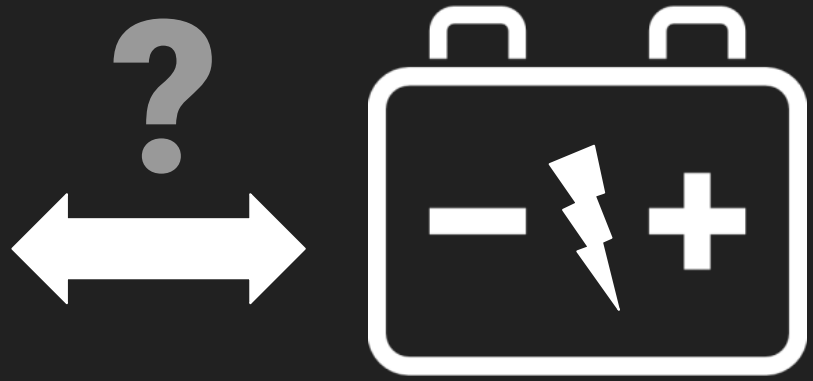


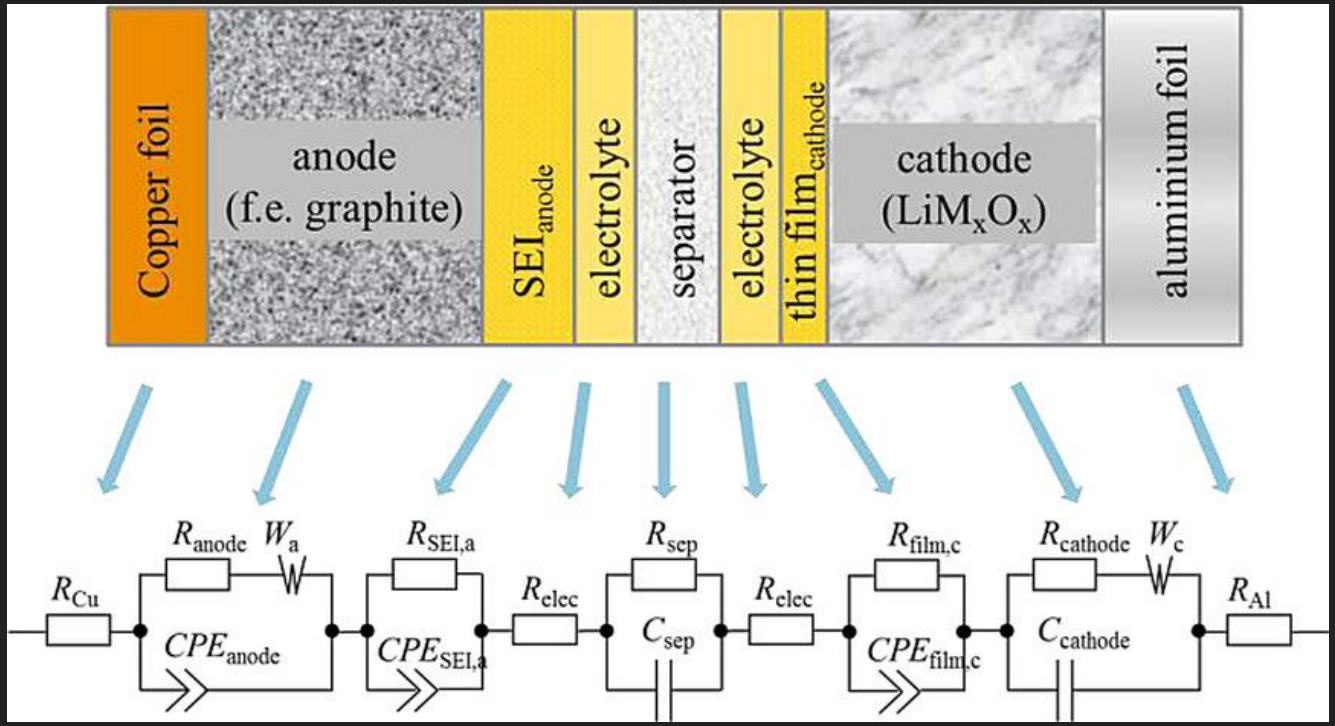
Energy

Cost

How do we use the EIS graph to simulate what's going on inside the battery?

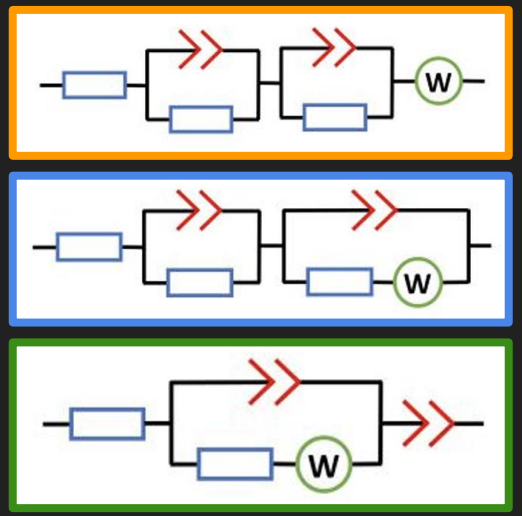


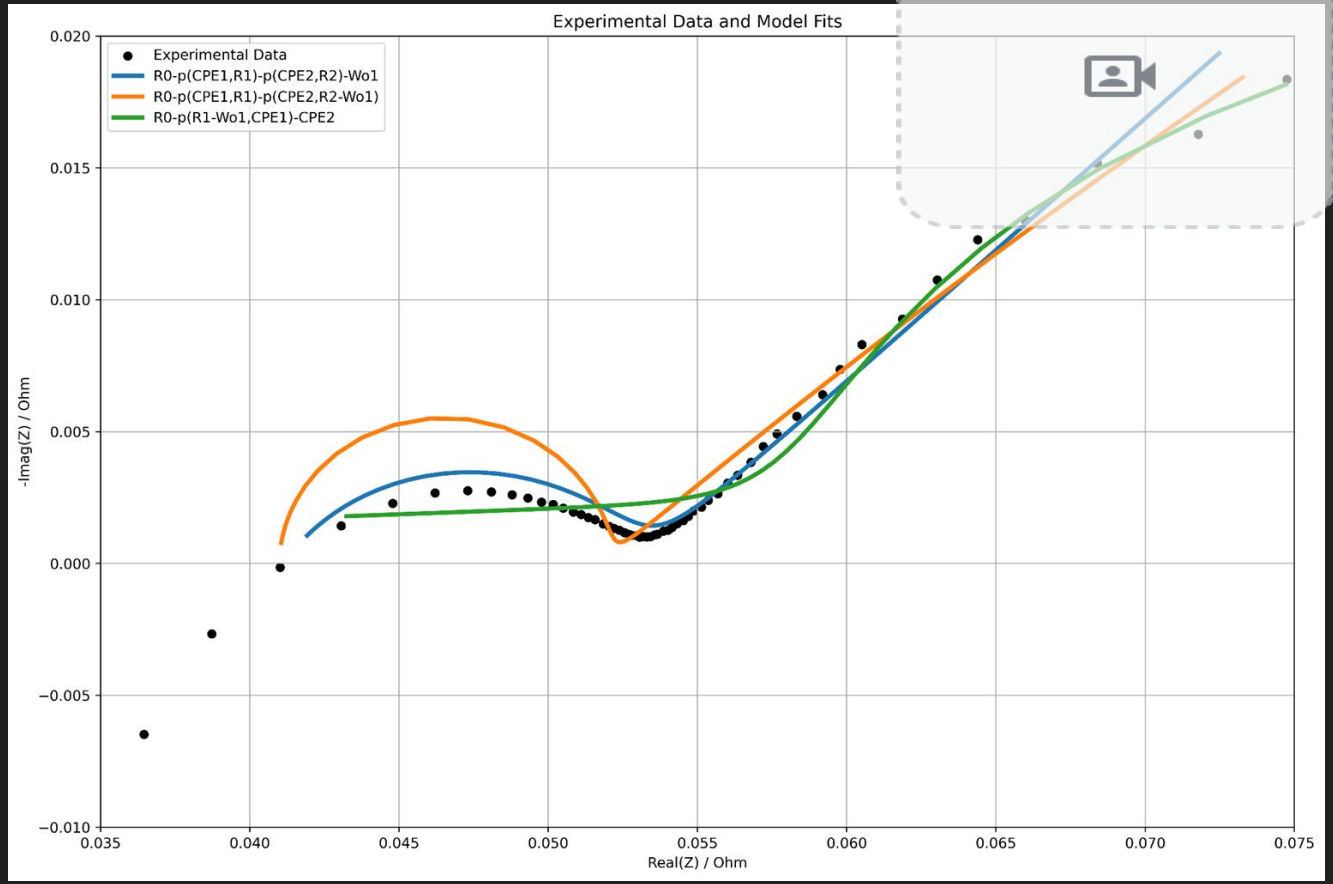




Westerhoff, U., Kurbach, K., Lienesch, F. & Kurrat, M., 2016. Analysis of Lithium-Ion Battery Models Based on Electrochemical Impedance Spectroscopy. Energy Technology, 4(12), pp.1620-1630. Available at: https://doi.org/10.1002/ente.201600154.

Fitting a circuit to EIS





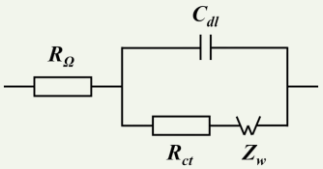
How does this help LiFETIME reach their goal?

Collect EIS data from batteries 10-15 minutes

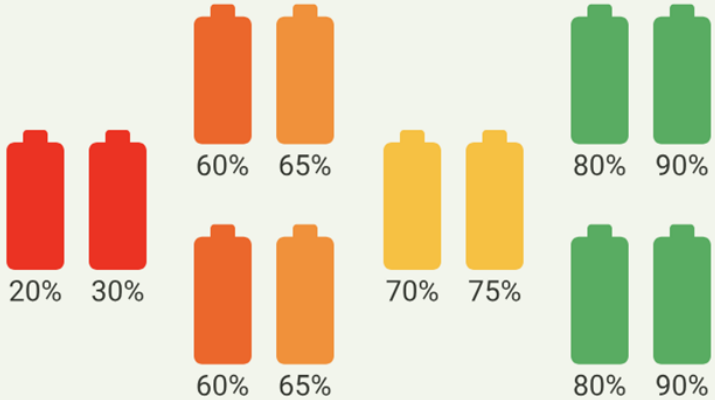
Aged first-life pack

LiFETIME+

Computer simulation



Device outputs remaining capacity

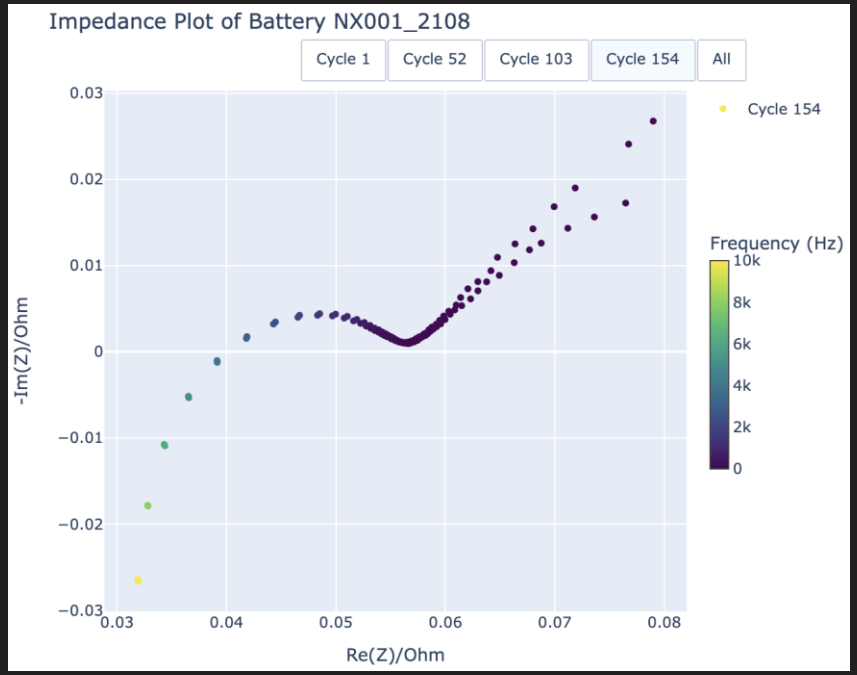


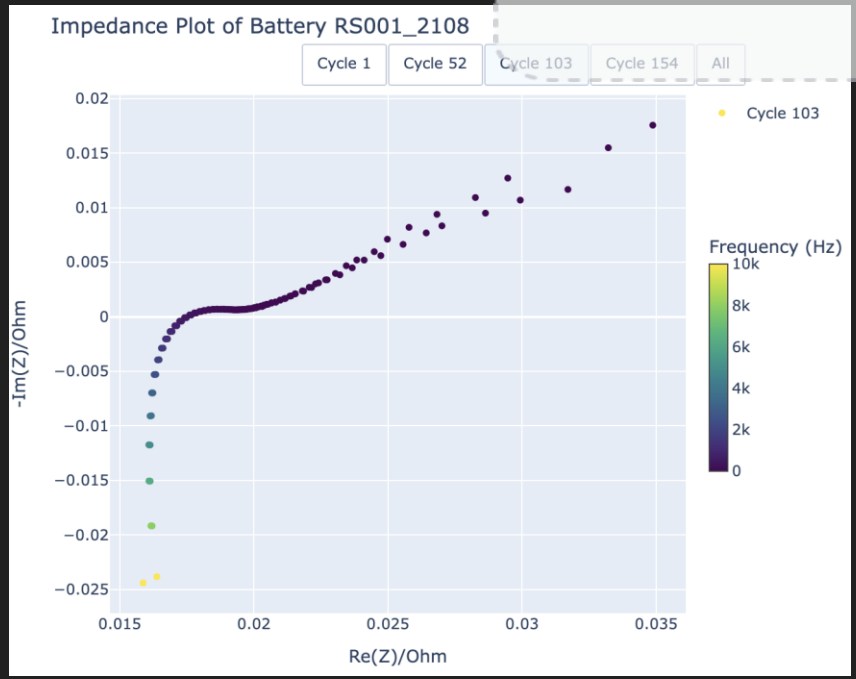
Suitable for recycling

Suitable for energy storage if grouped ±5%

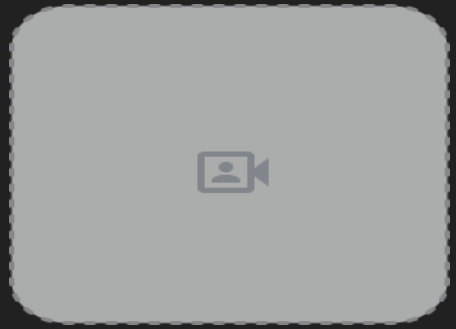
Suitable for EVs

Challenges of fitting circuit models

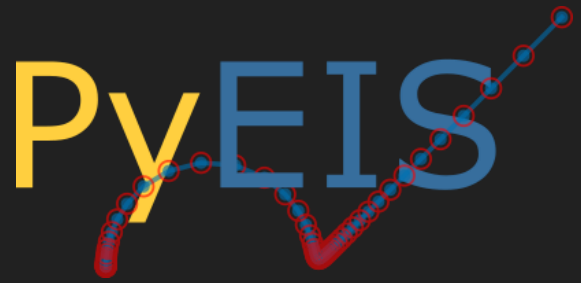




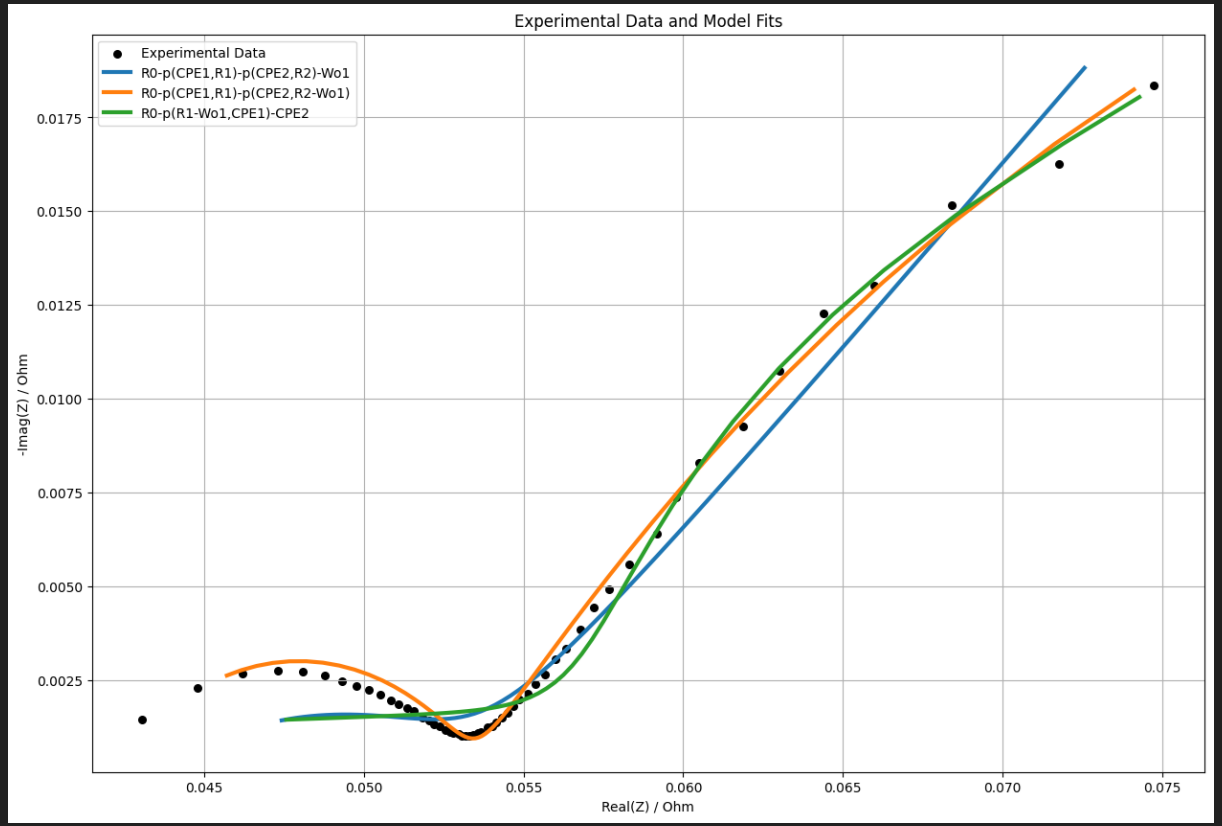
Software packages for circuit fitting



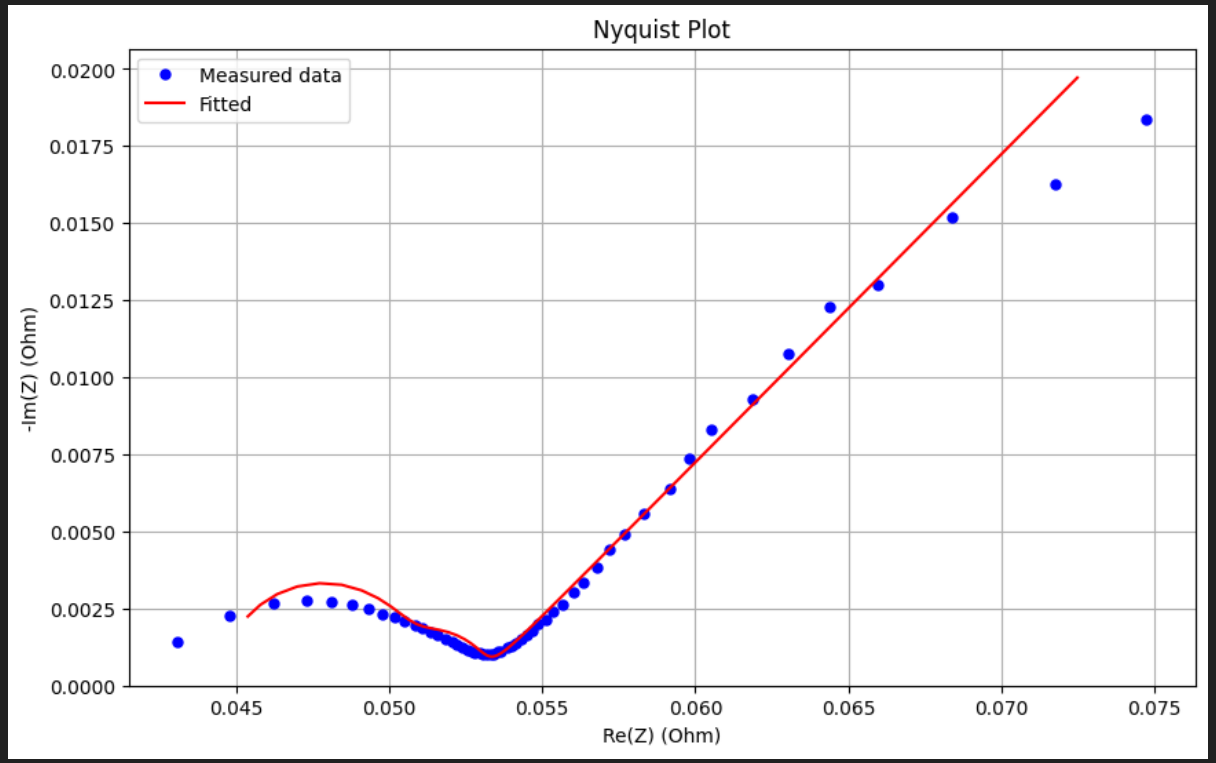
impedance.py



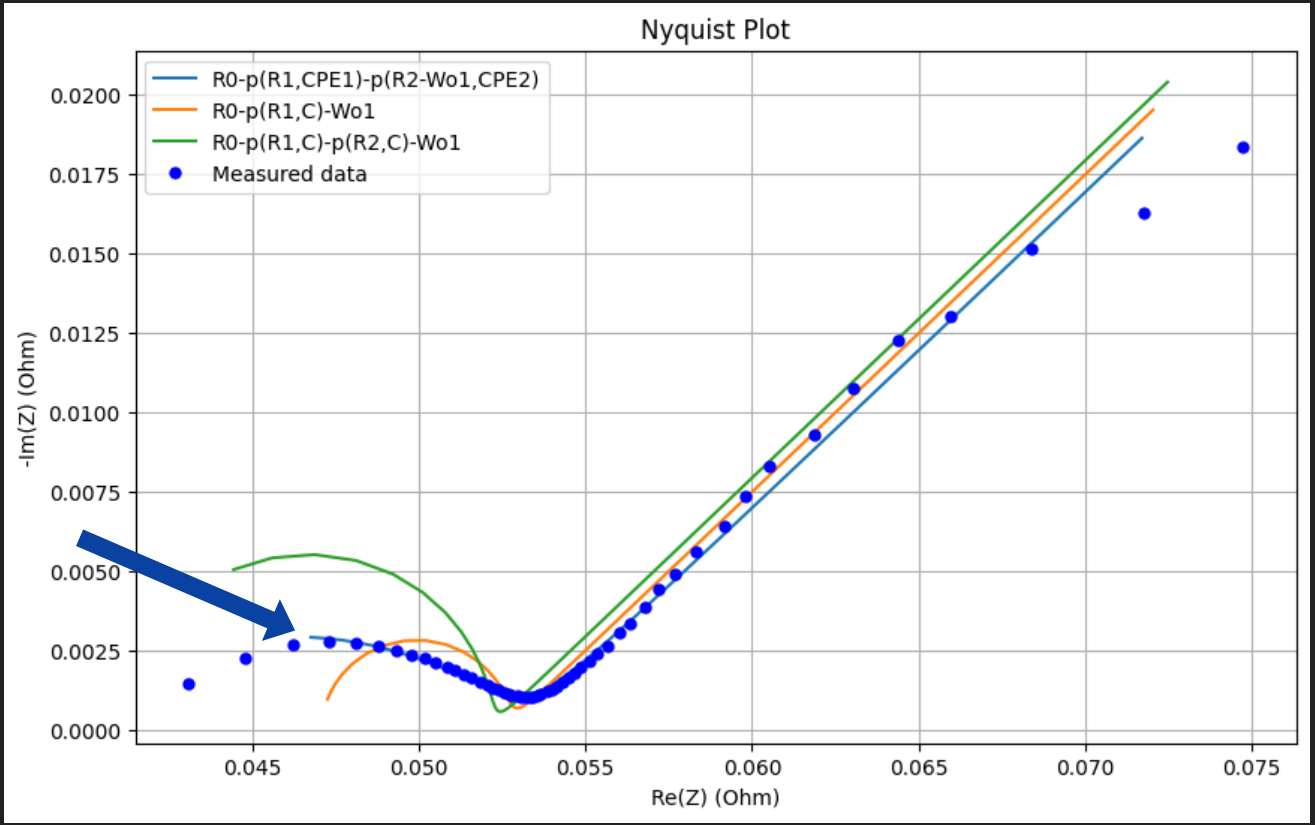
Impedance.py



Scipy.optimize



Scipy.optimise.curve_fit with KDE



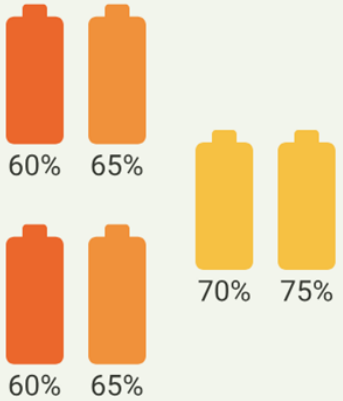
Summary

Capacity analysis
EIS testing
Fitting to a circuit model

Aged first-life pack

LIFETIME+

Suitable
for recycling



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References

- Slides 4,5:
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  - Danae, Lithium Iron Phosphate vs Lithium Cobalt Oxide (2020), Grepow [Link]
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  - Westerhoff, U., Kurbach, K., Lienesch, F. & Kurrat, M., 2016. Analysis of Lithium-Ion Battery Models Based on Electrochemical Impedance Spectroscopy. Energy Technology, 4(12), pp.1620-1630. Available at: https://doi.org/10.1002/ente.201600154.
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  - . Lohmann, N., Weßkamp, P., Haußmann, P., Melbert, J. & Musch, T. Electrochemical impedance spectroscopy for lithium-ion cells: Test equipment and procedures for aging and fast characterization in time and frequency domain. J. Power Sources 273, 613–623 (2015).
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