Battery Cell Design: Insights Through AI and Simulation

From teardown analysis to AI-driven microstructure characterization and AVL CRUISE™ M

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Today’s Agenda



About AVL Battery



Introduction



The Challenge



The Solution



Audi e-tron Case Study



Conclusion and Summary

AVL Battery Solutions



Leading the Charge in Innovation, AVL Creates **Advanced Battery Solutions** Powering a Cleaner, Greener Tomorrow.

20+
Years of Experience

24
Global Battery Tech Center

1000+
Executed Battery Projects

5,700+
E-Mobility Experts

650
Battery Engineers

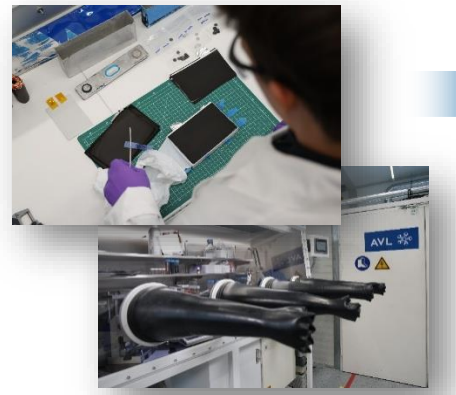
307
Battery Patents (Q4 2025, Patents or patent applications)

Accelerating Battery Development

From Cell Images to Engineering Insight

- Cell Teardown and electrode characterization
- AI-powered image analysis
- 3D microstructure reconstruction
- Extraction of key design parameters
- Virtual design exploration
- Accelerated battery development

Through Microstructure Intelligence



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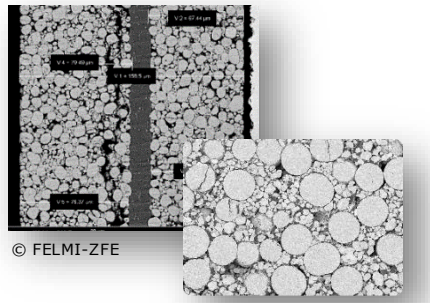

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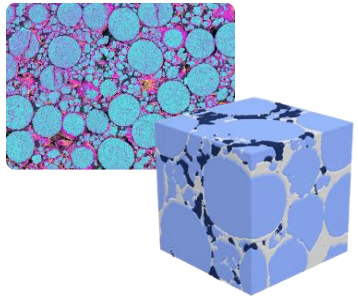

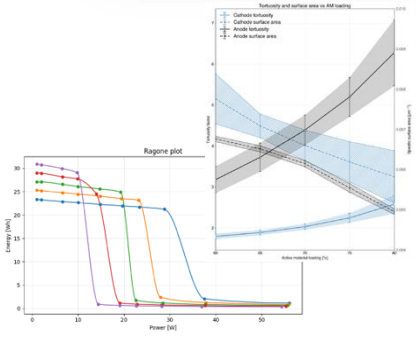

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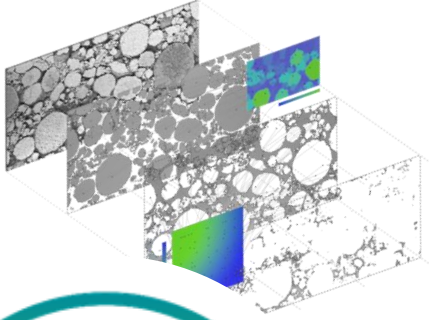
Research Question

Can we improve the Audi e-tron battery cell design by virtually optimizing its electrode microstructure for the WLTC duty cycle?





The Challenge



Limited transparency of internal cell design

- Electrode architecture, particle distribution, and pore networks are not directly accessible.
- Critical design parameters remain hidden behind supplier boundaries.

Manual and qualitative SEM analysis

- Interpretation relies heavily on expert judgement.
- No systematic extraction of quantitative descriptors.

Missing link between microstructure and performance

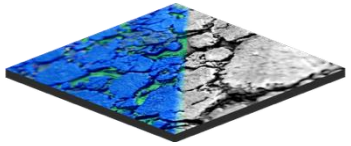
- Difficult to correlate features such as PSD, porosity, or tortuosity with electrochemical behaviour.
- Weak integration into simulation and modelling workflows.

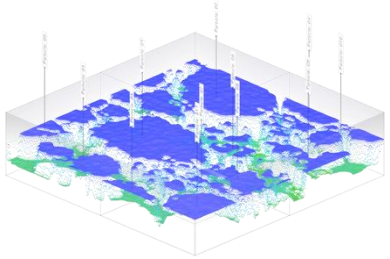
High effort and long turnaround times

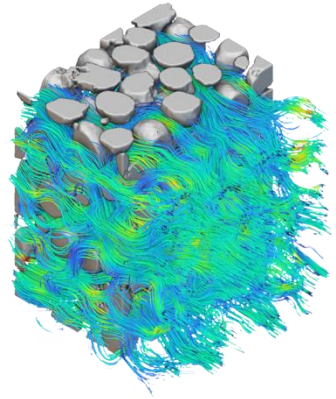
- Teardown and analysis workflows are labour-intensive.
- Advanced techniques (e.g. FIB-SEM) are costly and slow.

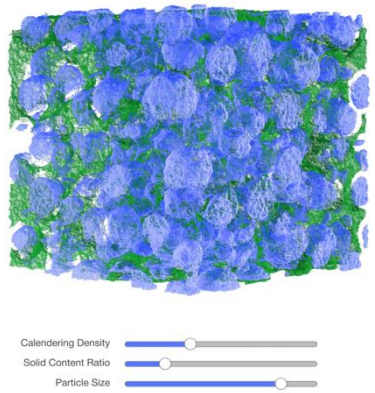
The Solution – Characterisation Focus











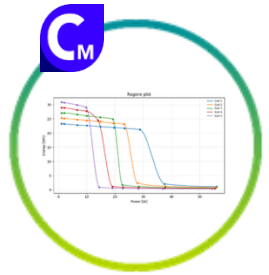


Image — **Segmentation** — **Particle Maps** — **Reconstruction** — **Design** — Insights

- Cell teardown
- Cross-sectional imaging

- Phase fractions
- Porosity
- Spatial phase distributions

- Particle sizes
- Particle morphology
- Interparticle distance

- 3D analysis
- Tortuosity
- Effective transport

- Explore microstructural design scenarios
- Optimise processing parameters

- Model parameterisation
- Cell performance assessment
- Electrochemical simulation

Vehicle Data AUDI e-tron 55 quattro 95kWh - MY2019





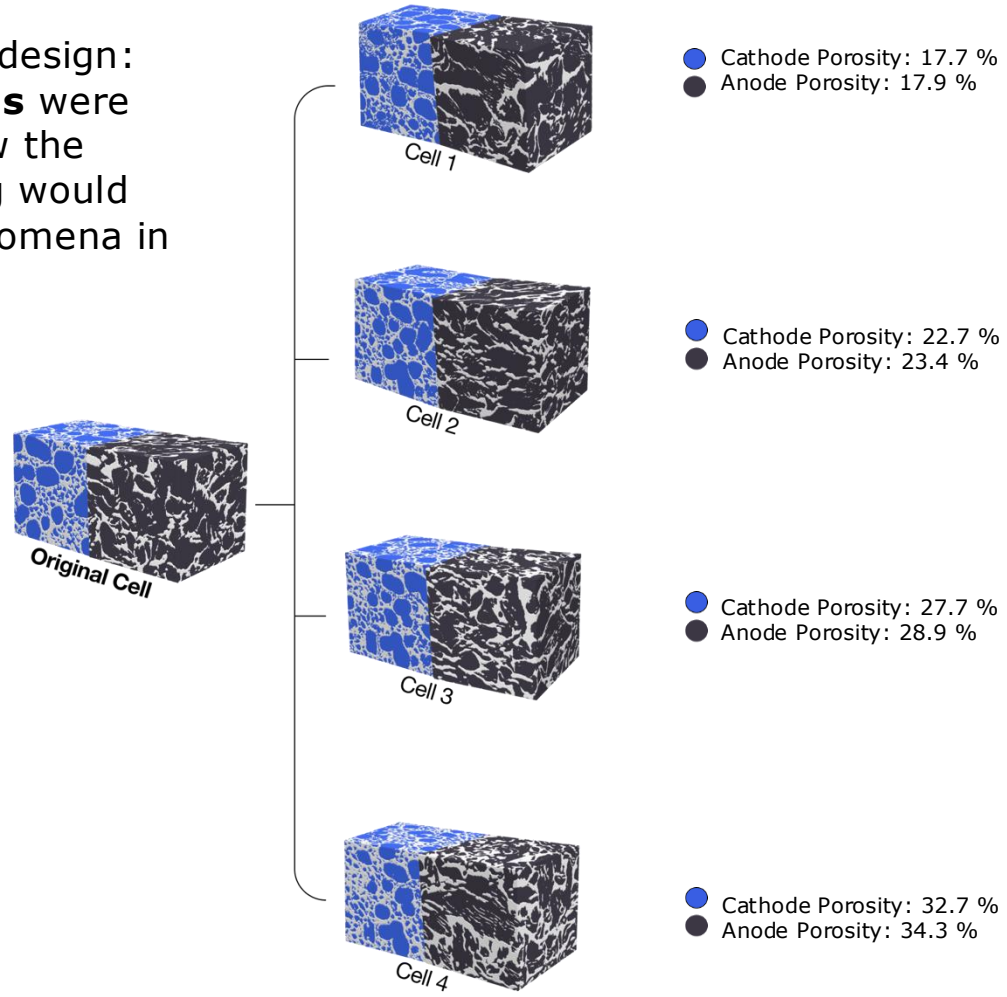


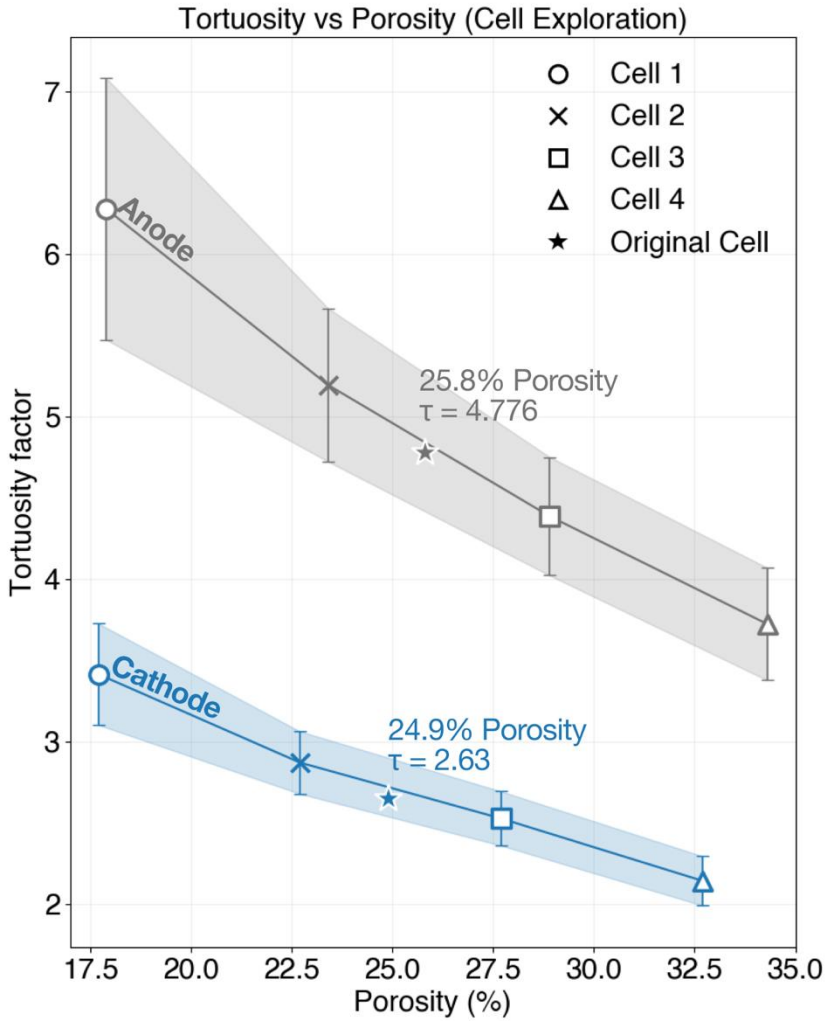
		Official	AVL
Vehicle Data	Power peak	265 kW	355 kW (HV-Battery power)
	Power continuous	158 KW	115-145 kW (HV-Battery power max. speed test)
	Top Speed	200 kph	198 kph
	Acceleration	6.6 s	5.8 s
	Range	417 km (WLTP cycle)	352/322 km (NEDC/WLTP cycle)
	Curb Weight	2565 kg (including 75kg driver)	2667 kg (including instrumentation)
Battery Data	Energy total	95 kWh	98.8 kWh (installed) (cell test)
	Voltage nominal	396 V	396 V
	Cell number	432	432
	Configuration	108s4p	108s4p
	Cooling	liquid	liquid
Cell Data	Cell manufacturer	LG Chemical	LG Chemical
	Cell type	E61V Pouch	E61V Pouch
	Chemistry	Graphite / NMC622	Graphite / NMC622
	Nominal capacity	60.0 Ah	62.1 Ah
	Nominal Voltage	3.68 V	3.69 V

Source: https://www.audi.at/e-tron/e-tron/technik/technische-daten | AVL ... measured values during benchmark

Microstructural Exploration

From one original cell design: **several permutations** were created to explore how the active material loading would impact transport phenomena in each scenario.





Design Influence on Cell Performance

- **Microstructure determines the energy-power trade-off.**
- **Higher active material**

  loading increases energy density but reduces porosity.
- **Transport limitations**

  lead to polarization and performance loss at high C-rates.
- **AVL CRUISE™ M Electrochemical simulations**

  enable virtual optimization of electrode designs.
- **Faster development**

  through reduced experimental validation effort.

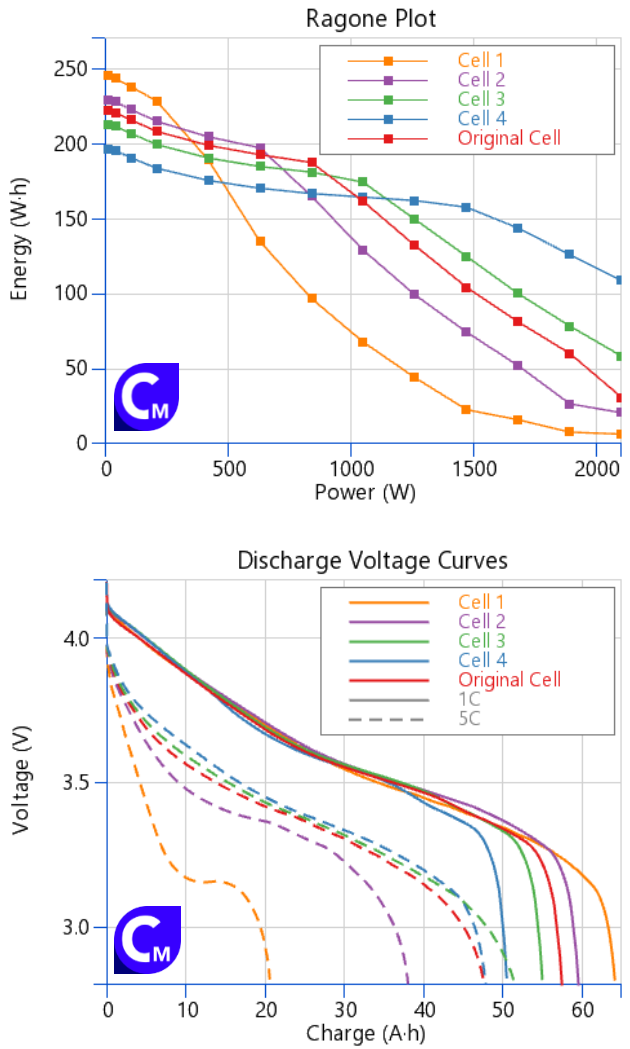
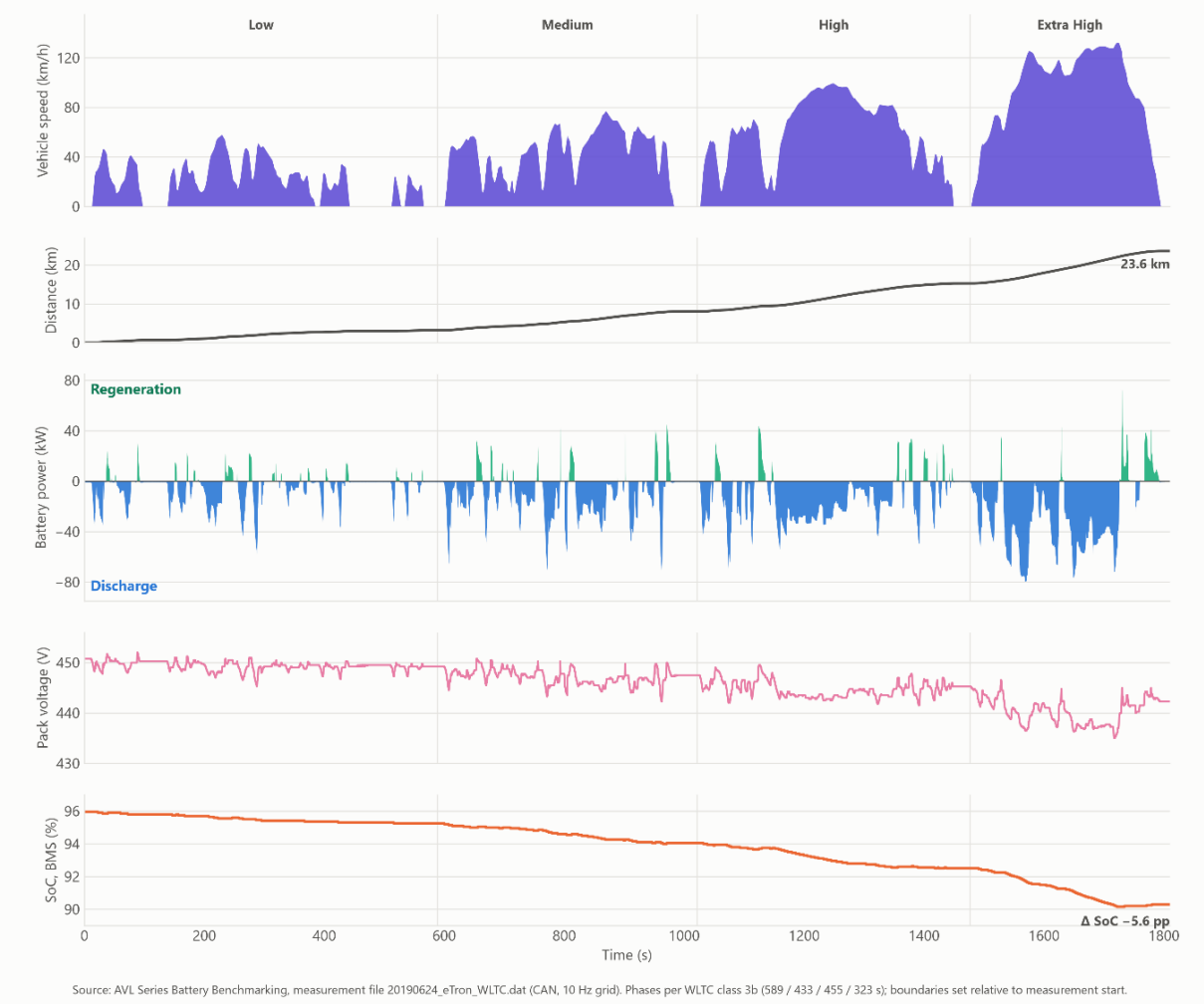


Fig. 7. Ragone plots (top) and discharge curves (bottom) for each cell case obtained through simulation in CRUISE M. ©AVL List GmbH, 2026

Audi e-tron 55 – WLTC: 80kW peak on a 355 kW pack



Source: AVL Series Battery Benchmarking, measurement file 20190624_eTron_WLTC.dat (CAN, 10 Hz grid). Phases per WLTC class 3b (589 / 433 / 455 / 323 s); boundaries set relative to measurement start.

23.6 km

- 1800 s Duration
- Four WLTC phases
- Up to 132 km/h

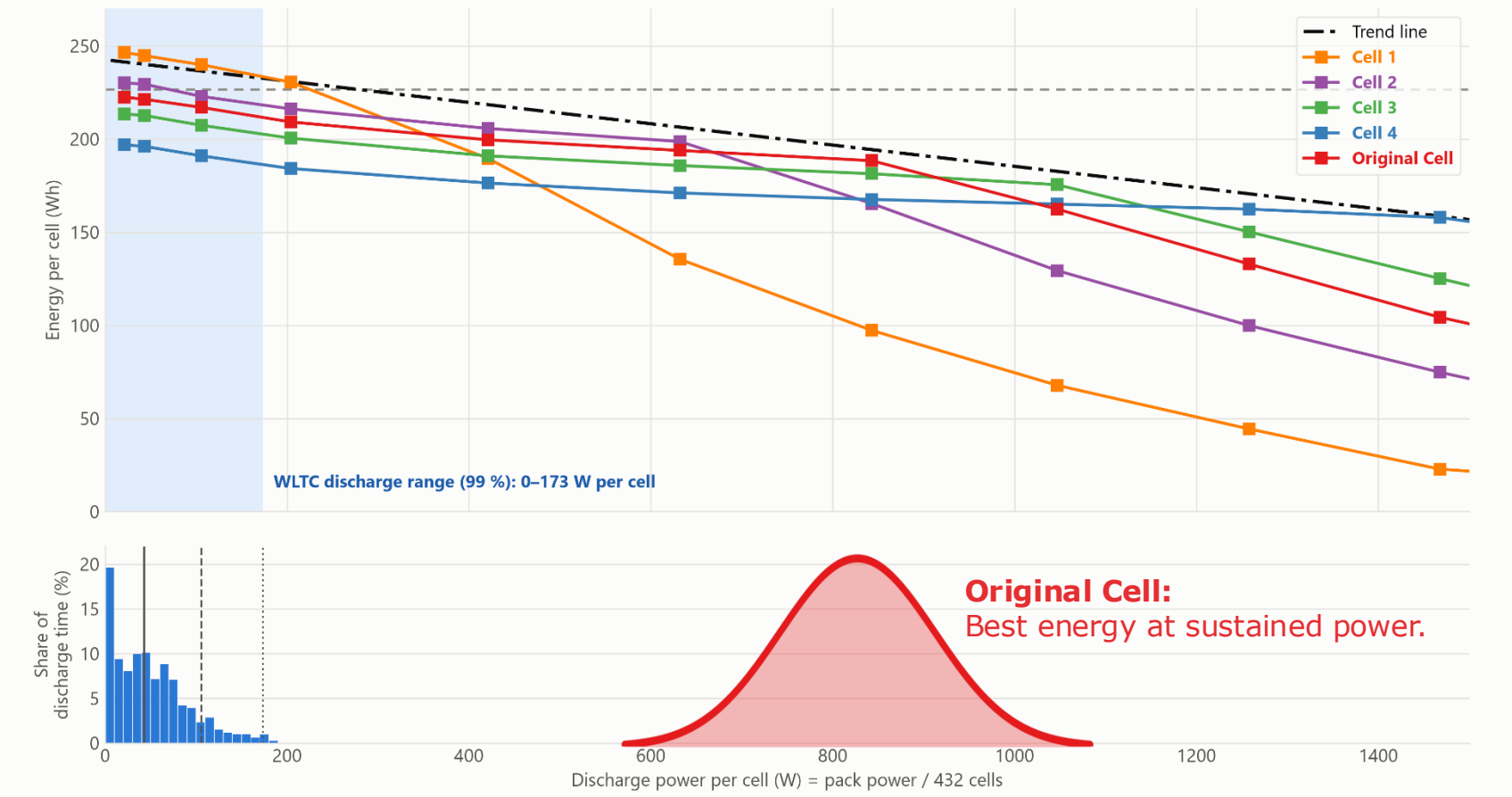
80 kW

- Peak power discharge
- Ø 17.5 kW while discharging

-5.6 pp

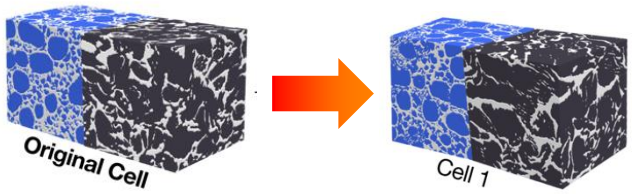
- SoC over one cycle
- 96.0 → 90.3 %

Trading power for energy pays off in the WLTC



+11 %

Energy in the same cell volume under WLTC load.



Yes, the cell can be improved for the WLTC: At a cell load of at most 185 W, a lower-porosity electrode delivers +11 % energy at unchanged cell volume.

Areas of Further Development

Quasi-static evaluation

- Energy is interpolated from constant-power Ragone curves.
- Transient polarization, relaxation and self-heating are neglected.

Single operating point

- 23 °C, 96 → 90 % SoC, new cells.
- Resistance and transport limits depend strongly on T and SoC.

Use-case coverage

- WLTC only: peak power (≈ 820 W/cell) and fast charging are not assessed.
- Above ~350 W/cell the original cell delivers more energy

Ageing and manufactur-ability

- Lower porosity raises plating, cracking and swelling risk.
- Calendering and electrolyte wetting at 17.7 % porosity are open process questions.





Takeaway

Microstructure simulation brings virtual battery development to the electrode level: Design the cell for its use case, not for the datasheet.

Thank you



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Public

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White Paper Download:

AVL & Polaron



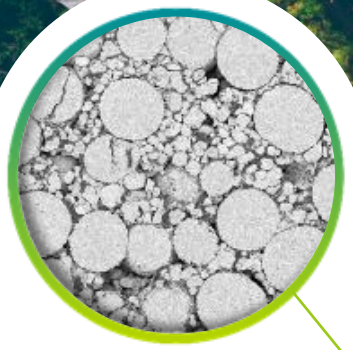
Together, we are leveraging electrochemistry and artificial intelligence to accelerate the development of next-generation battery materials, paving the way for faster innovation, sustainable energy storage, and future e-mobility solutions.

Microstructure Intelligence for Virtual Battery Development

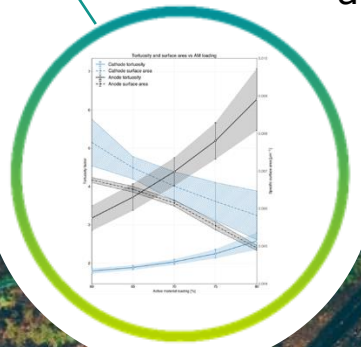
Quantify microstructure beyond visual inspection.



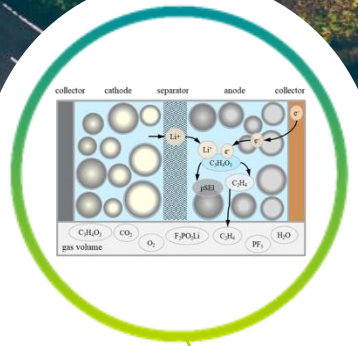
Reveal hidden electrode design characteristics.



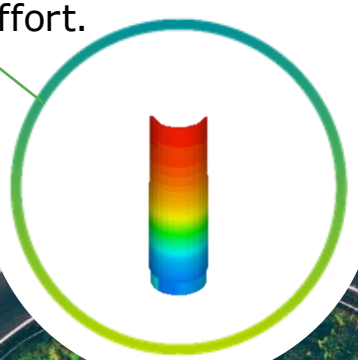
Connect structural features to cell performance.



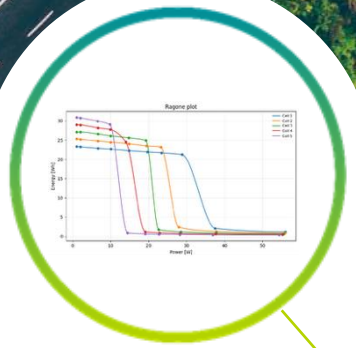
Capture ion transport, reaction kinetics, SEI and gas formation.



Reduce development time and testing effort.



Evaluate design trade-offs through simulation.



Full-system simulations for real-world reliability.



Optimizing module design features for swelling and thermal loads.

