eMPROVE

Innovative solutions
for the industrialization
of electrified vehicles

eMPROVE – Industrialization of electric vehicles

→ EV battery-packs at low temperature

A3PS Conference, Vienna
November 9, 2017

Introduction

eMPROVE

Innovative solutions for the industrialization of electrified vehicles

eMPROVE aims at

- innovative solutions for the **industrialization of electrified vehicles**
- **increasing** both **energy** and **cost efficiency**
- focusing on possibilities for future **industrial mass production**.

eMPROVE aims will be accomplished

- by **improving dedicated** vehicle **components** (e.g. transmission, energy storage systems),

eMPROVE solutions will be demonstrated by

- a **PHEV full vehicle** and a **modularized battery pack system**

Consortium

eMPROVE
Innovative solutions for the industrialization of electrified vehicles

klima+ energie fonds

AVL

Saubermacher

REDUX
sort & recycle smart!

SAMSUNG SDI

SAMSUNG

virtual vehicle

MONTAN UNIVERSITÄT

AIT AUSTRIAN INSTITUTE OF TECHNOLOGY

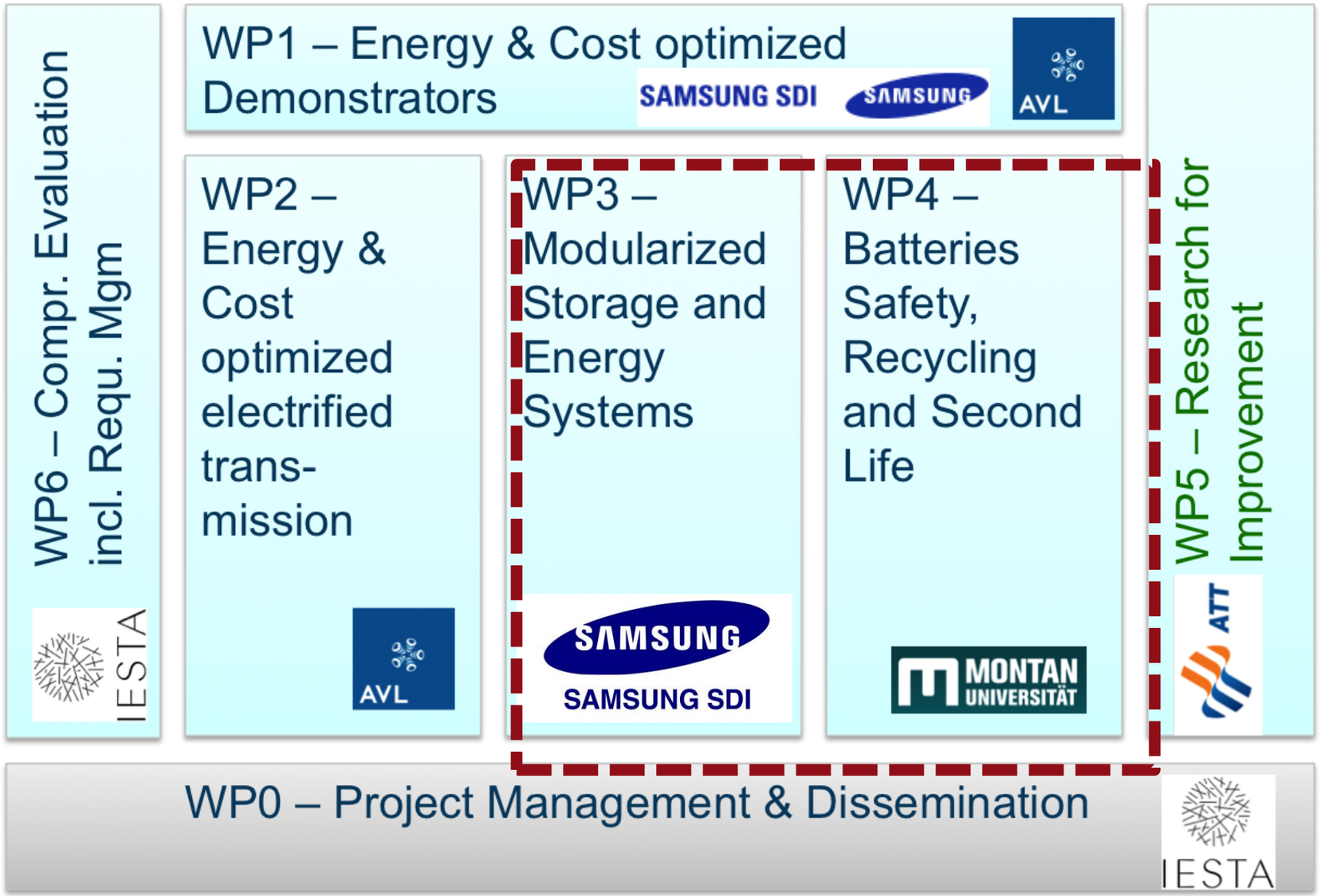
ATT

4a MANUFACTURING GmbH

ZOERKLER
the spirit of precision

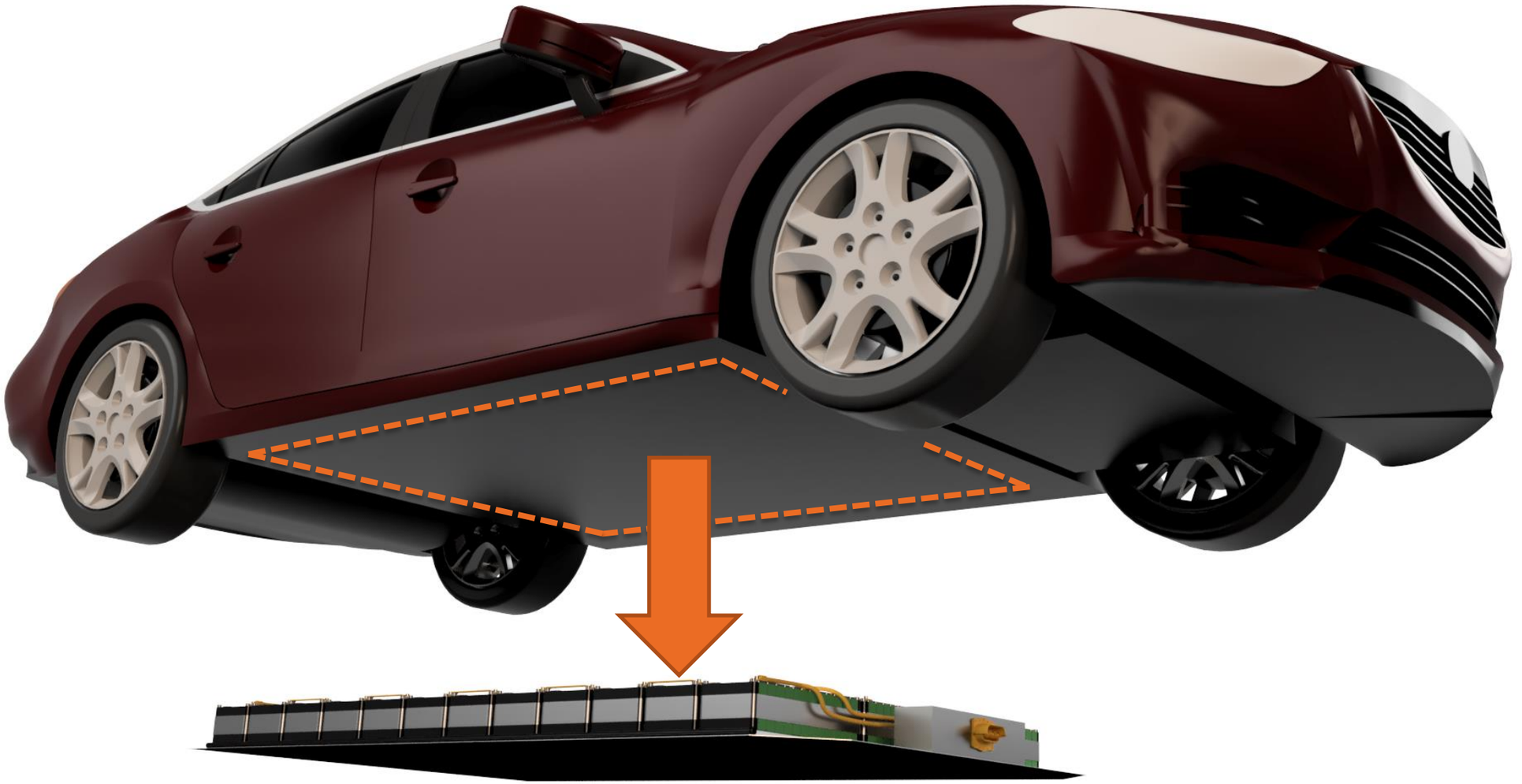
IESTA

eMPROVE Project structure



- **WP3 → Improved Storage and Energy Systems**: Battery cost reduction by min. 15%; increase of energy density by min. 20%
- **WP4 → Improved Battery Safety, Recycling & Second life**: Establish safe recycling processes for batteries and chargers; establish second life concepts for batteries and chargers

Electric Vehicle



Operation in low temperature

Li-ion batteries below 0°C

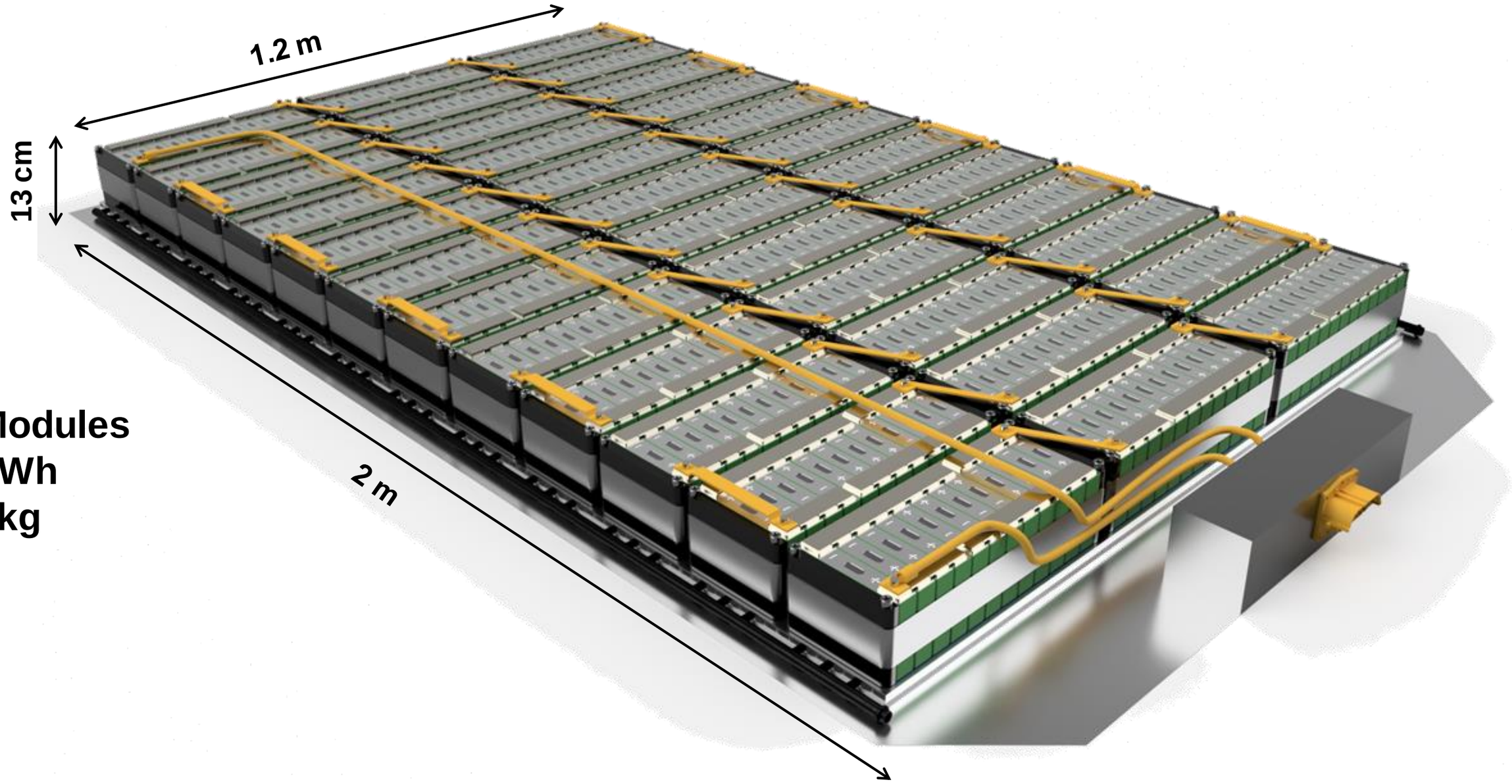
- **Low power**
- **Risk of Li-plating:**
- **Capacity decrease**
- **Safety risks**

Introduction of battery packs for EV

Operation at low temperature

New concepts for thermal management

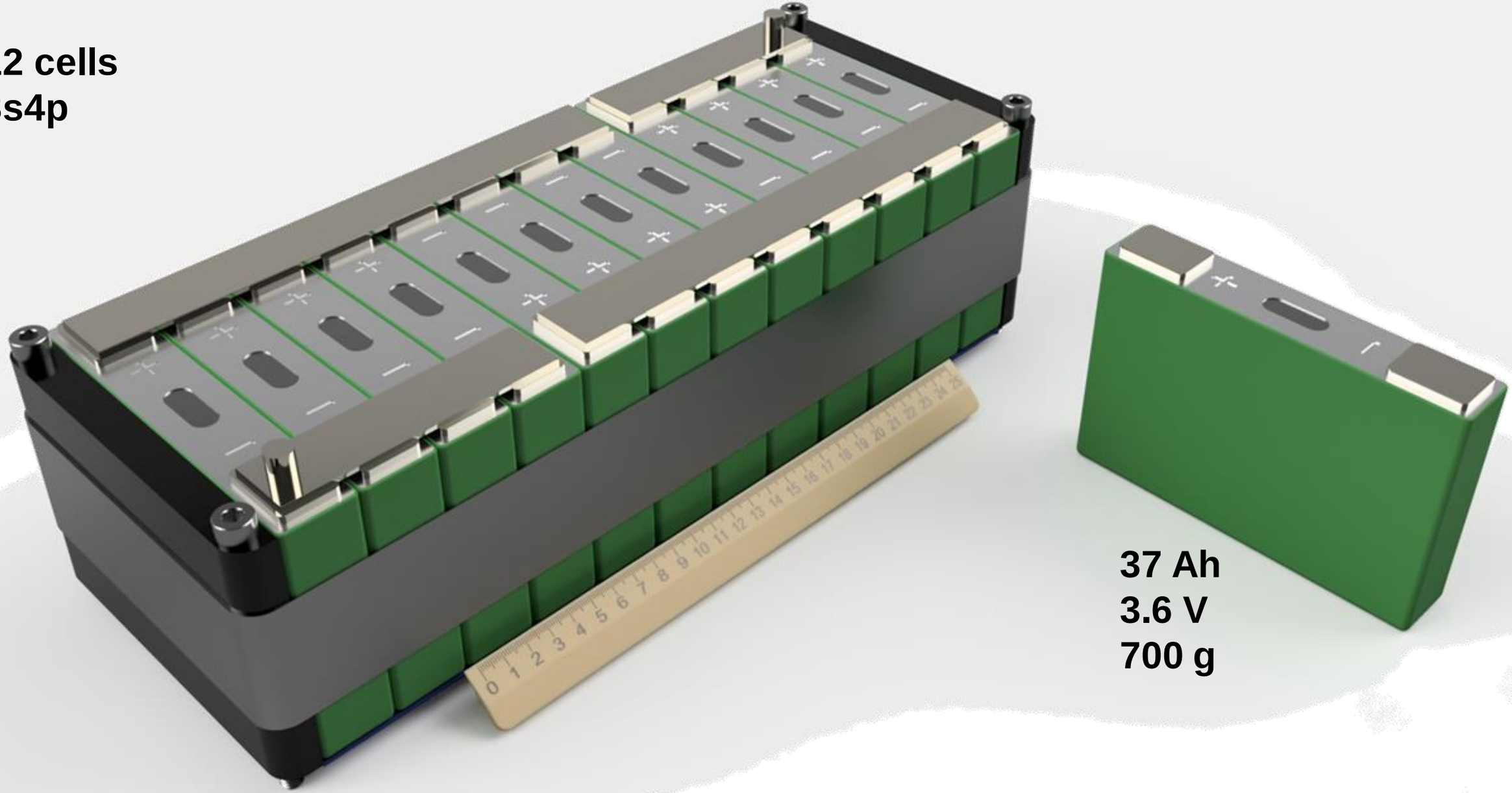
Battery pack for EV



36 Modules
60 kWh
300 kg

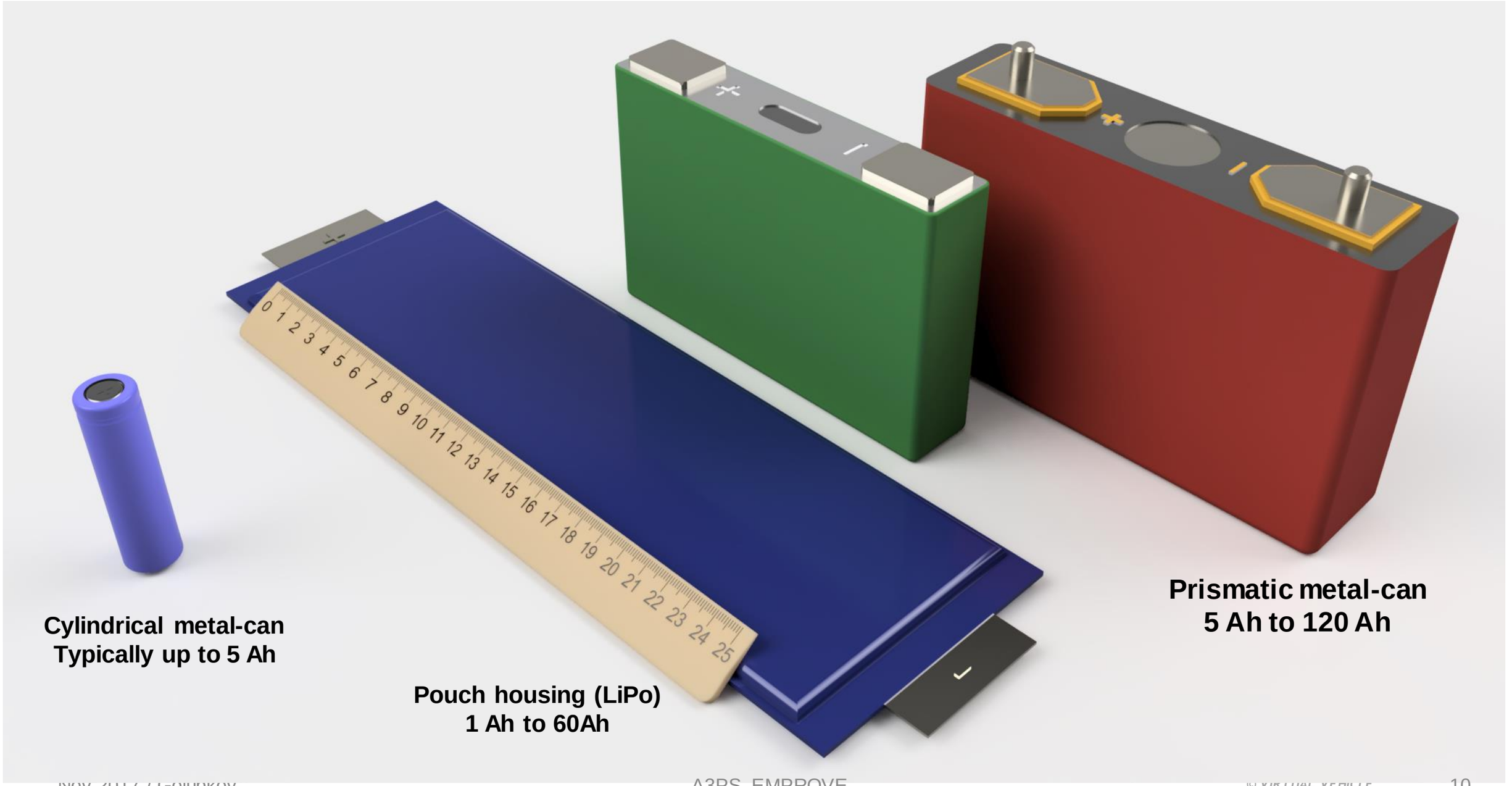
Battery module

12 cells
3s4p

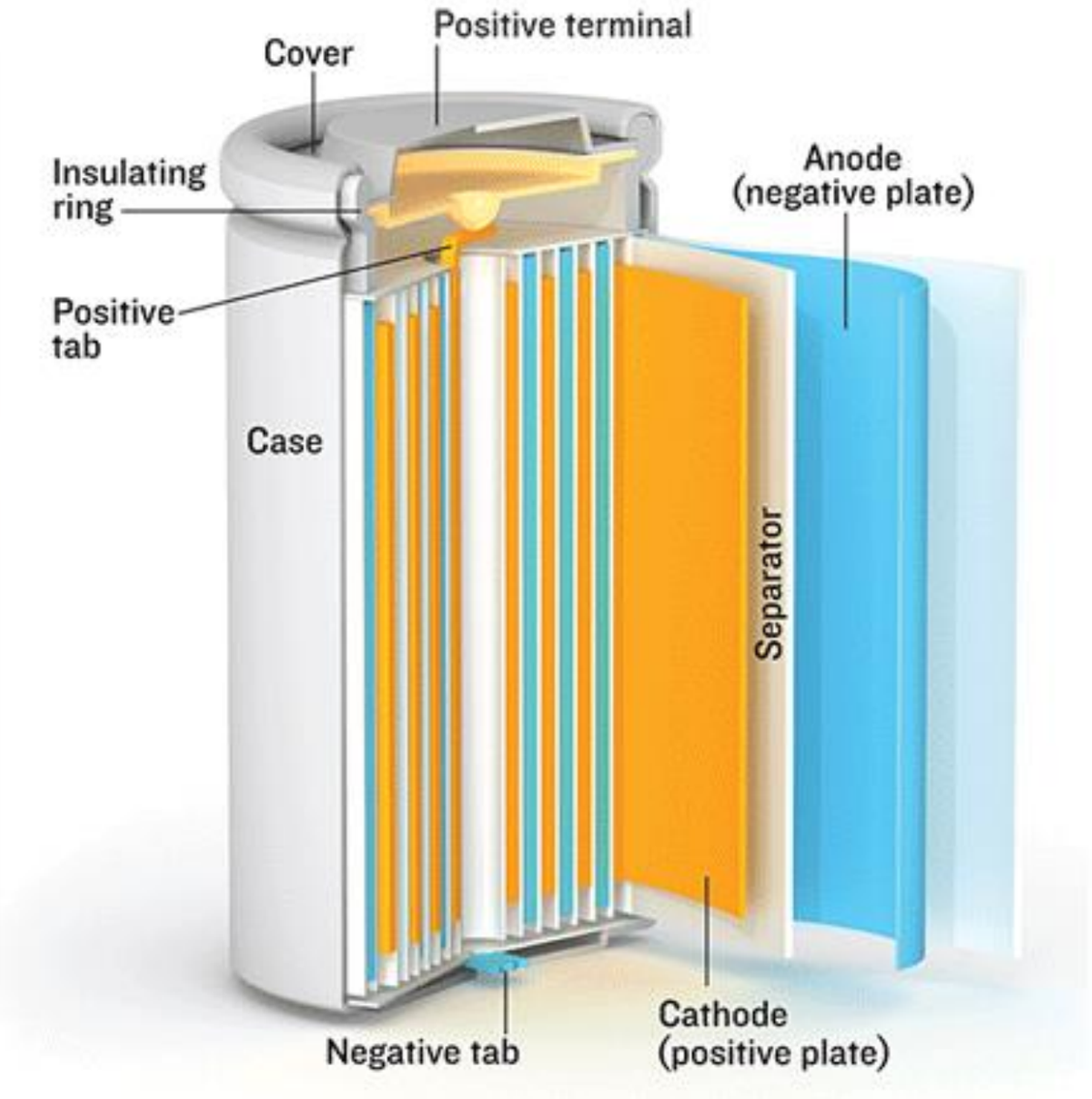


37 Ah
3.6 V
700 g

Different cell geometries



Inside a cylindrical metal-can cell



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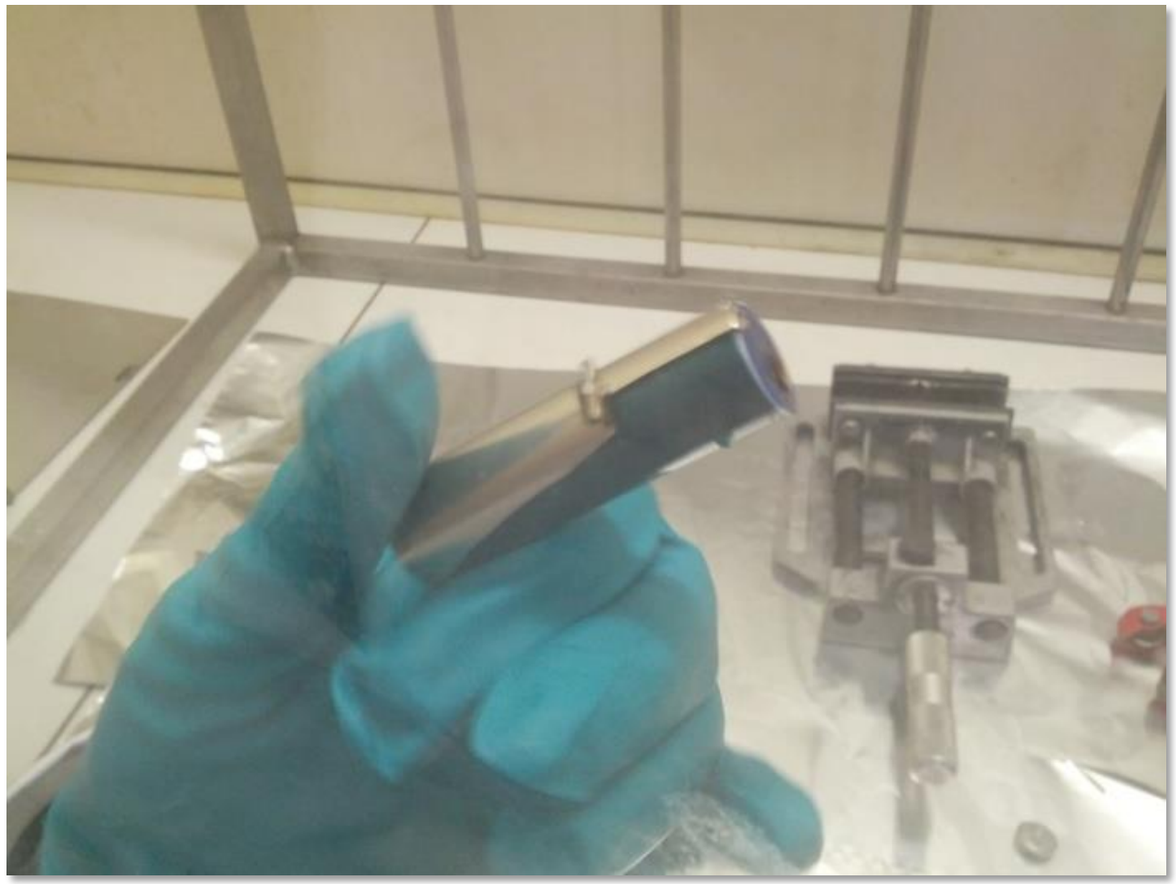

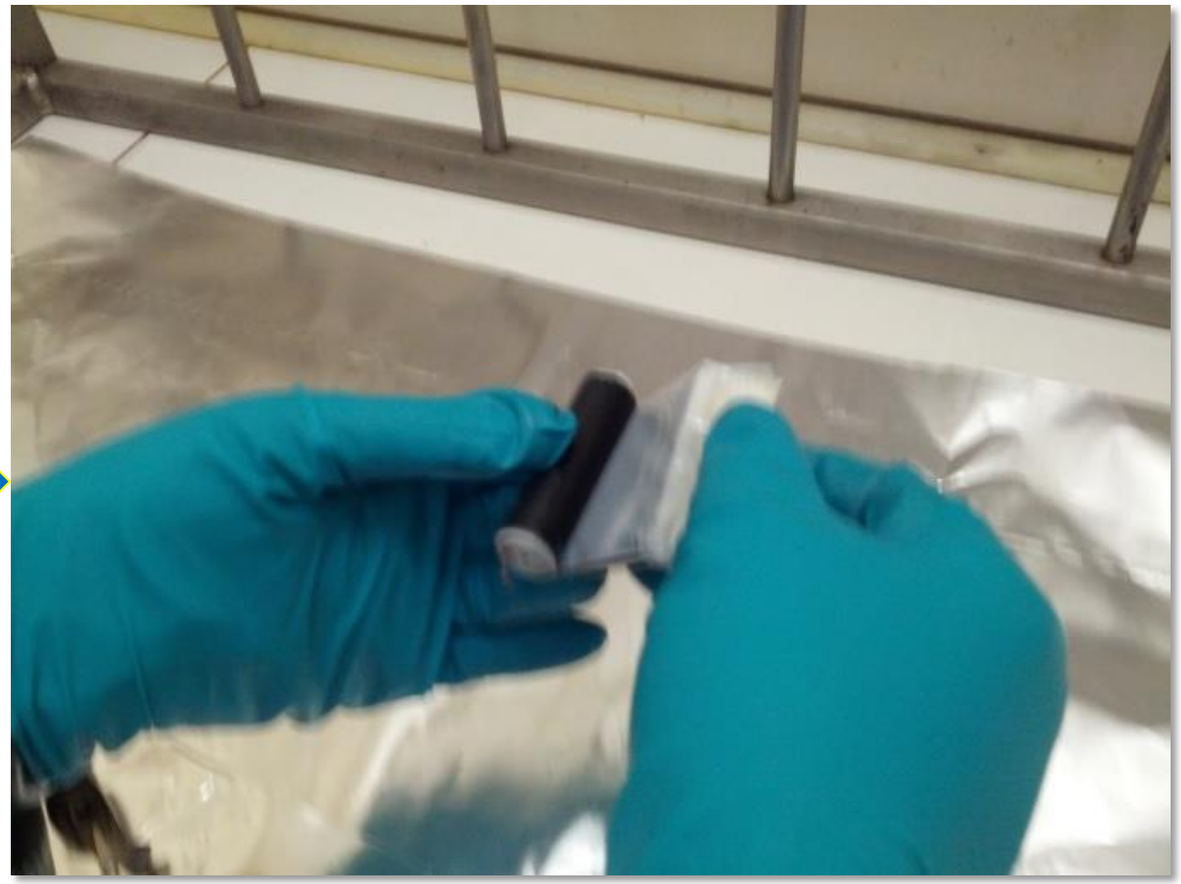

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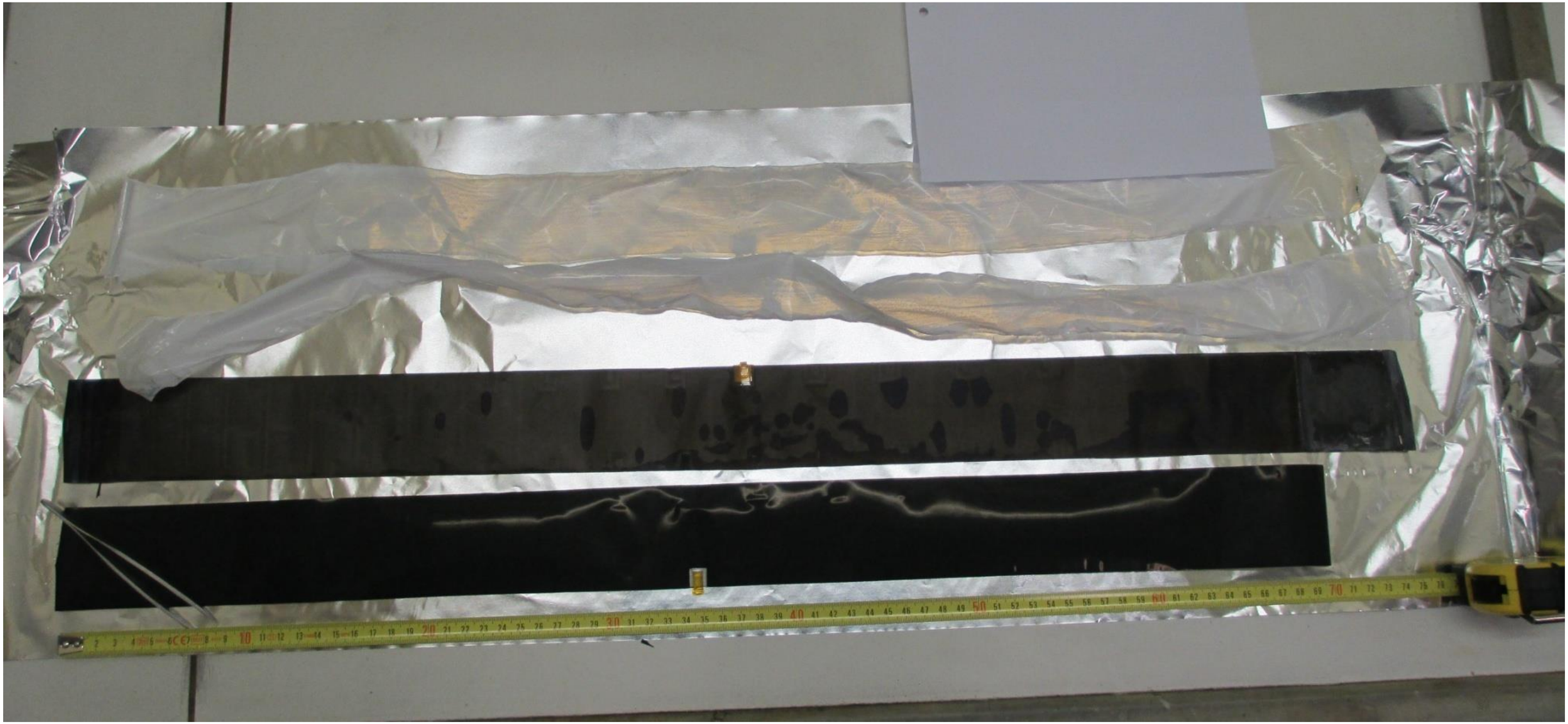
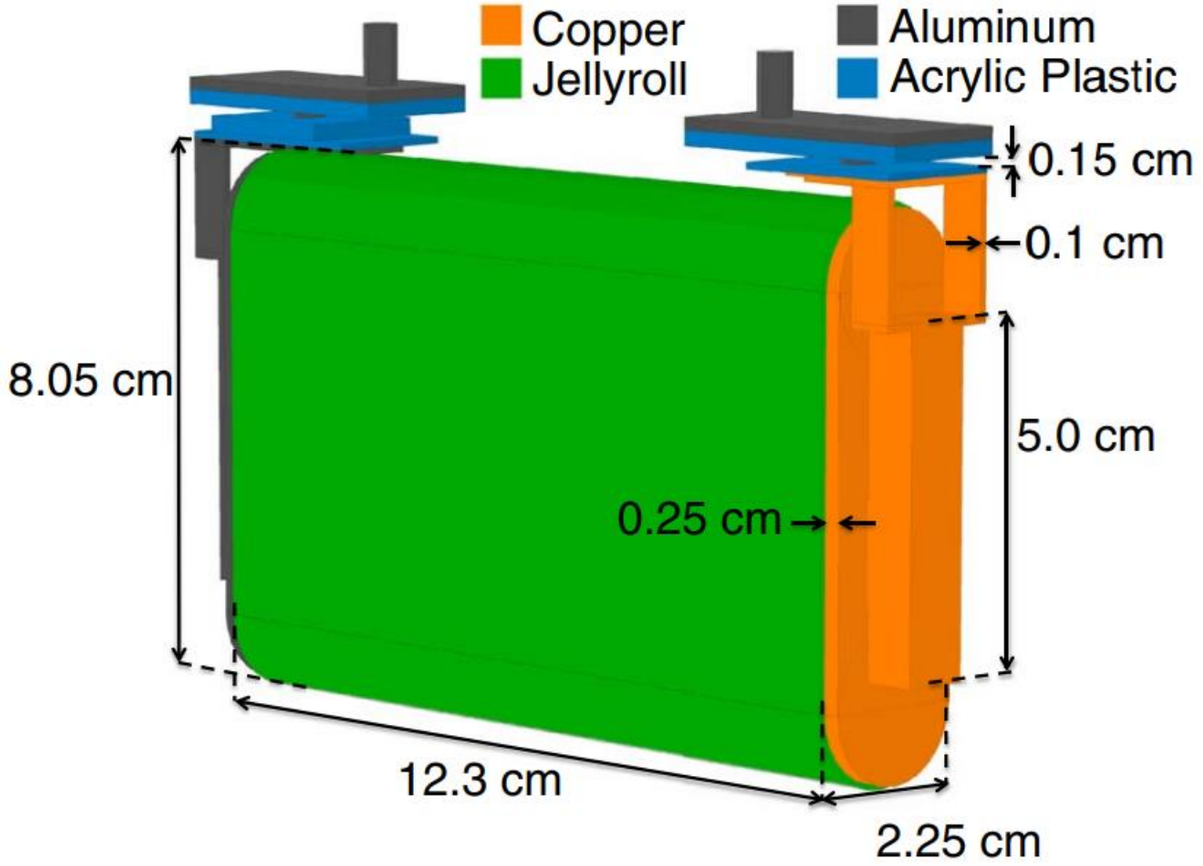
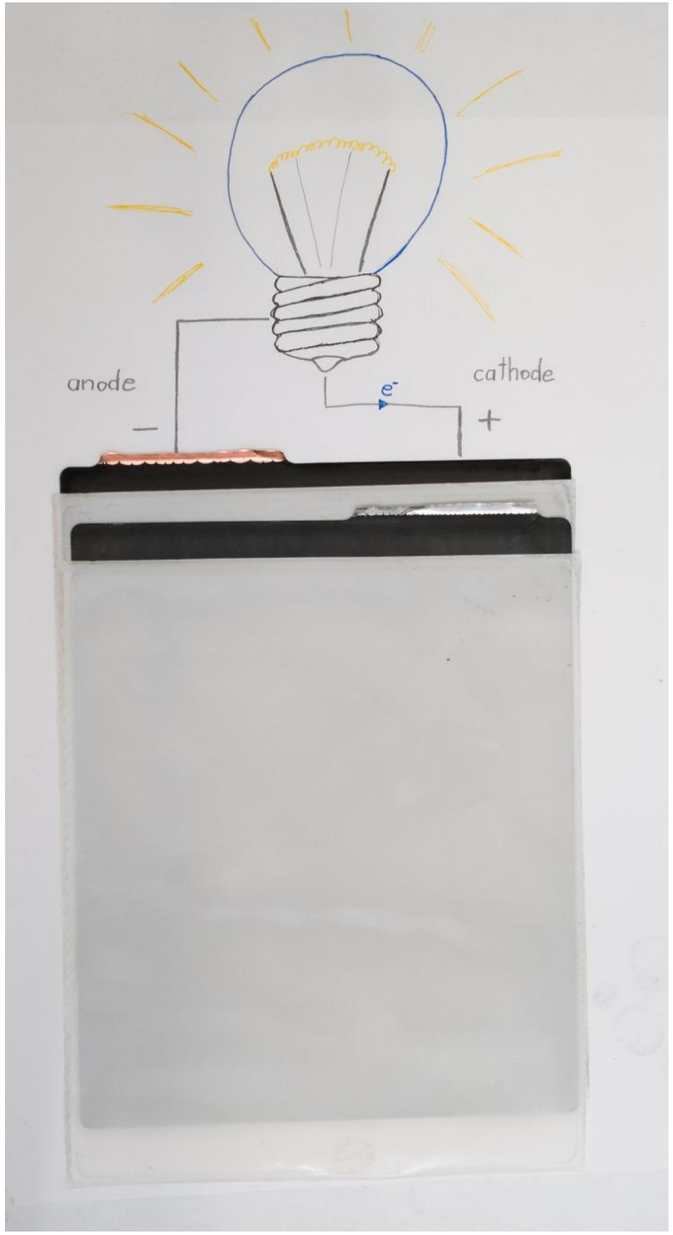


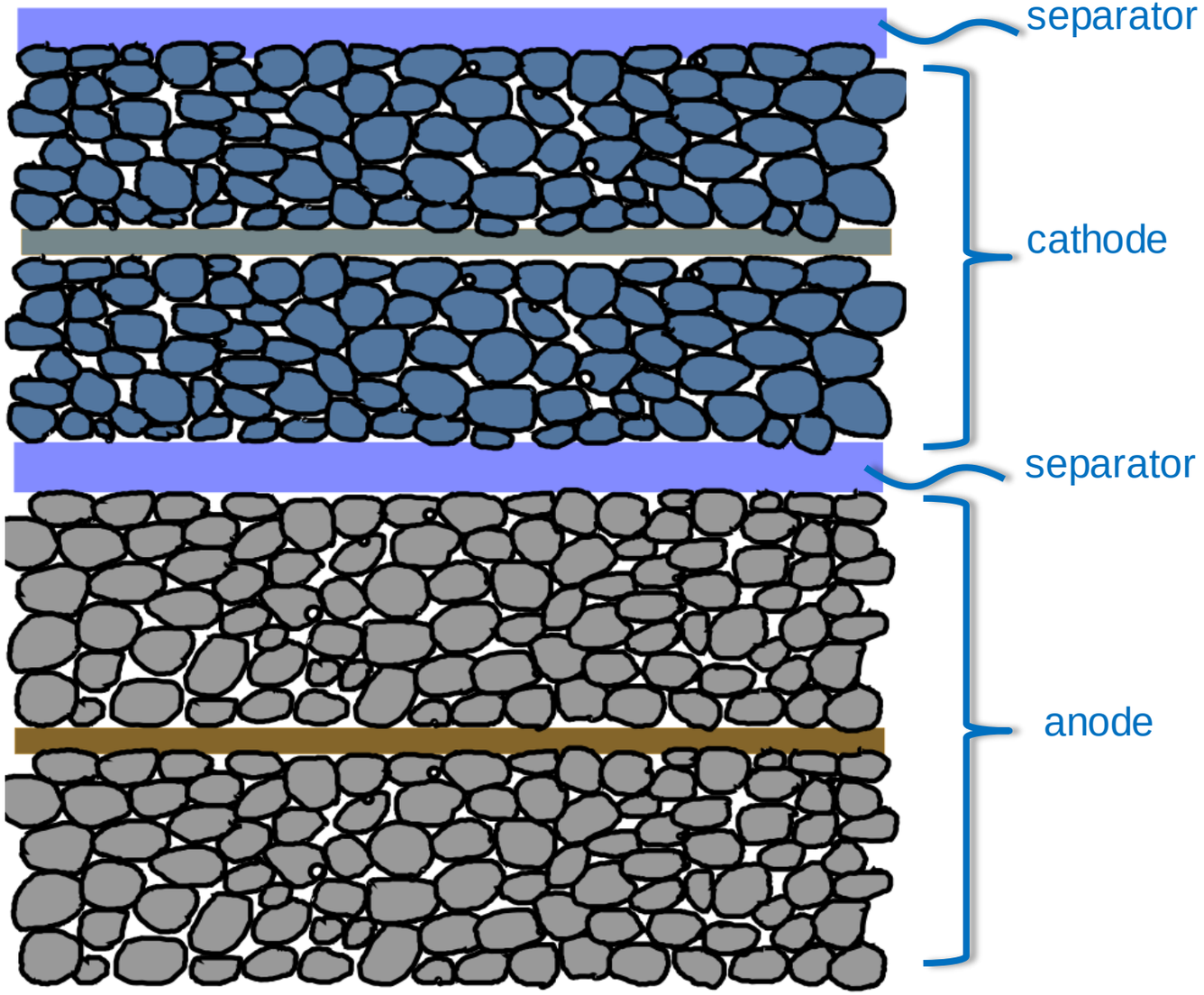
Inside prismatic metal-can cell



Henrik Lundgren et al. J. Electrochem. Soc. 2016;163:A309-A317

Electrode assembly



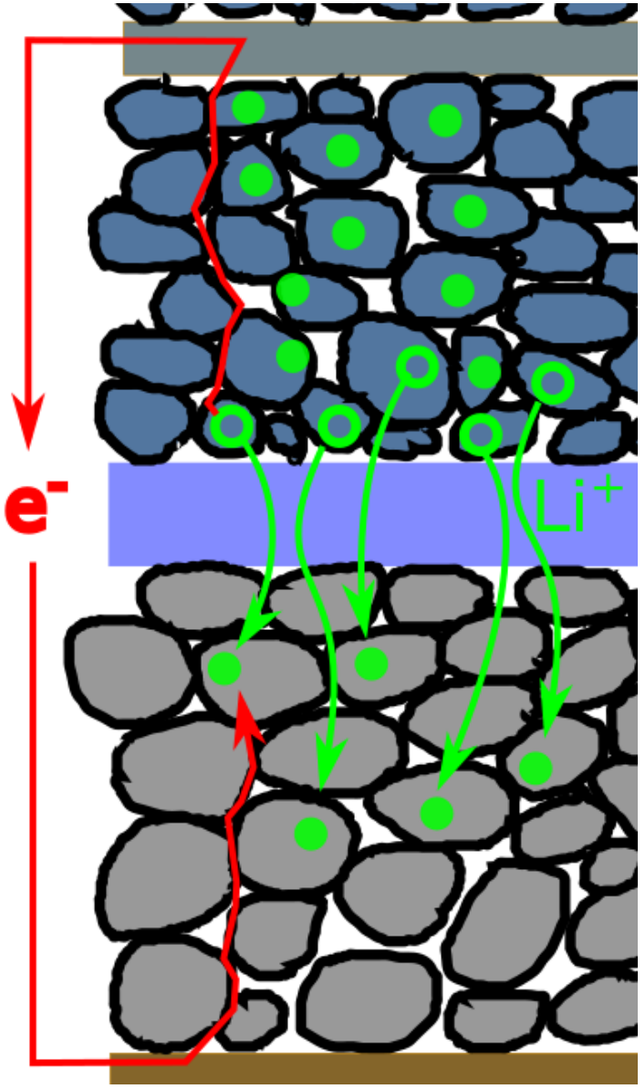


Introduction of battery packs for EV

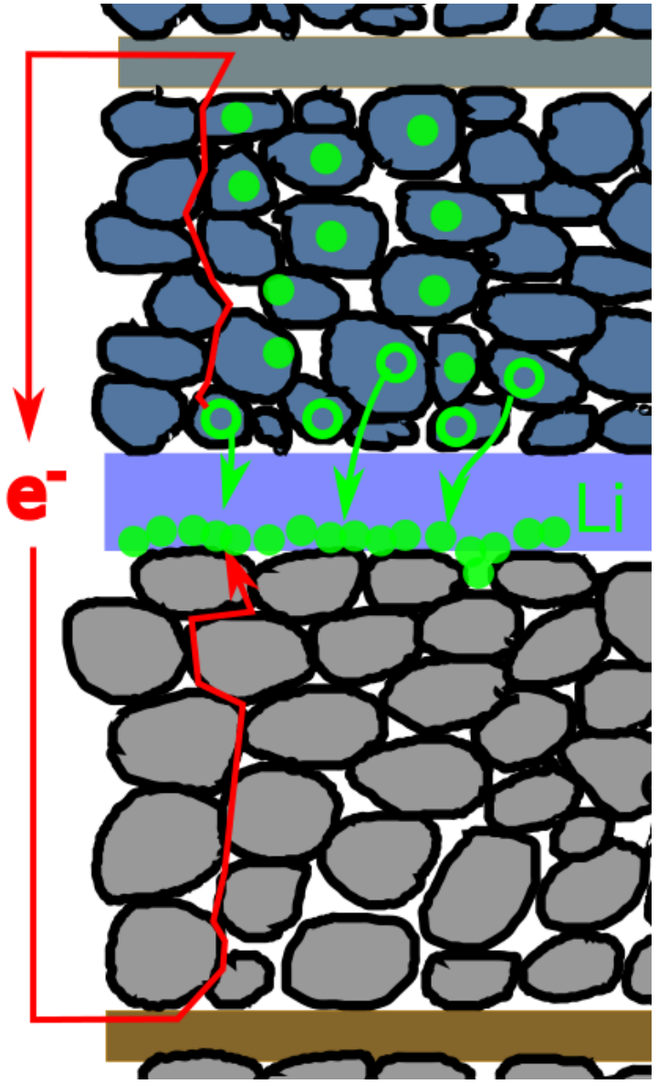
Operation at low temperature

New concepts for thermal management

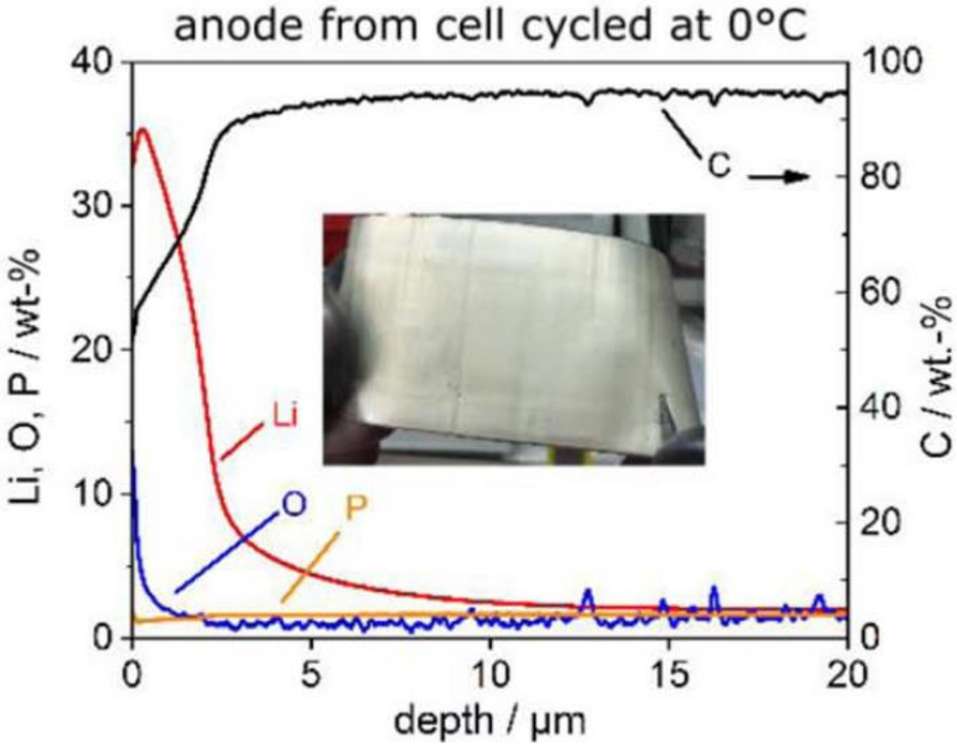
Li-plating during charge



Moderate temperature
Slow charge

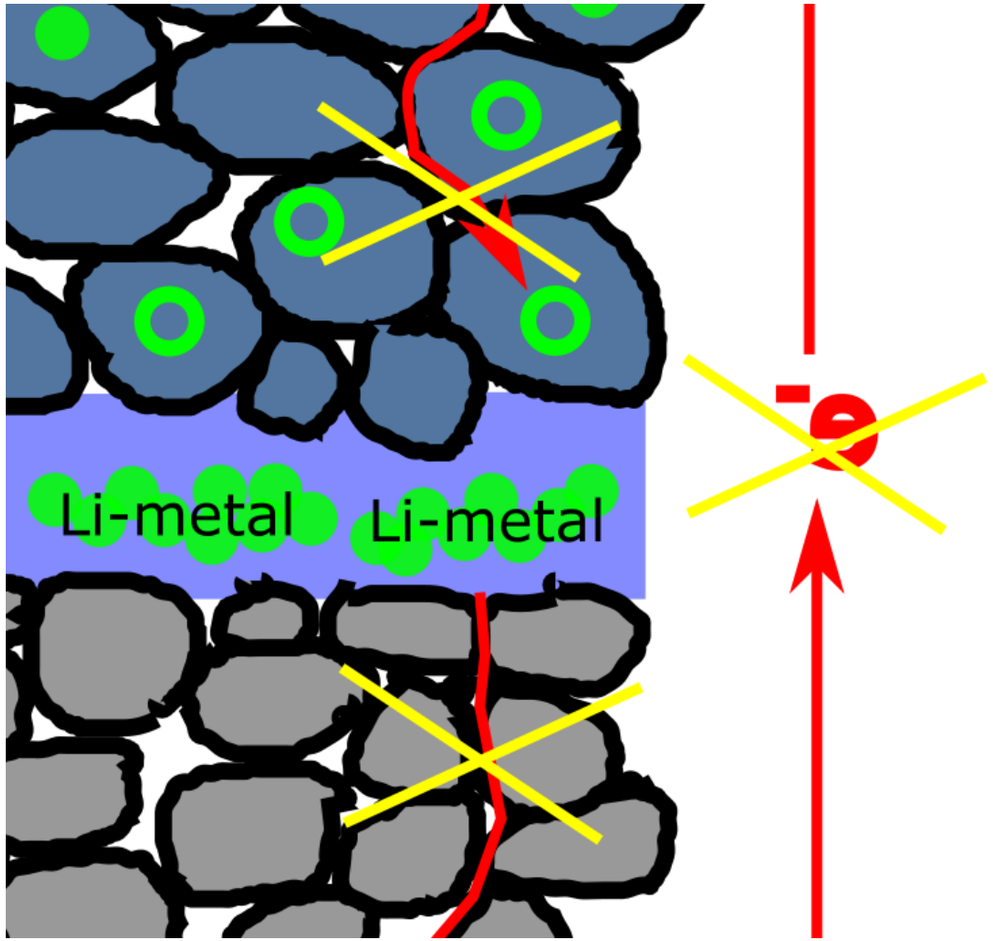


Low temperature
Fast charge

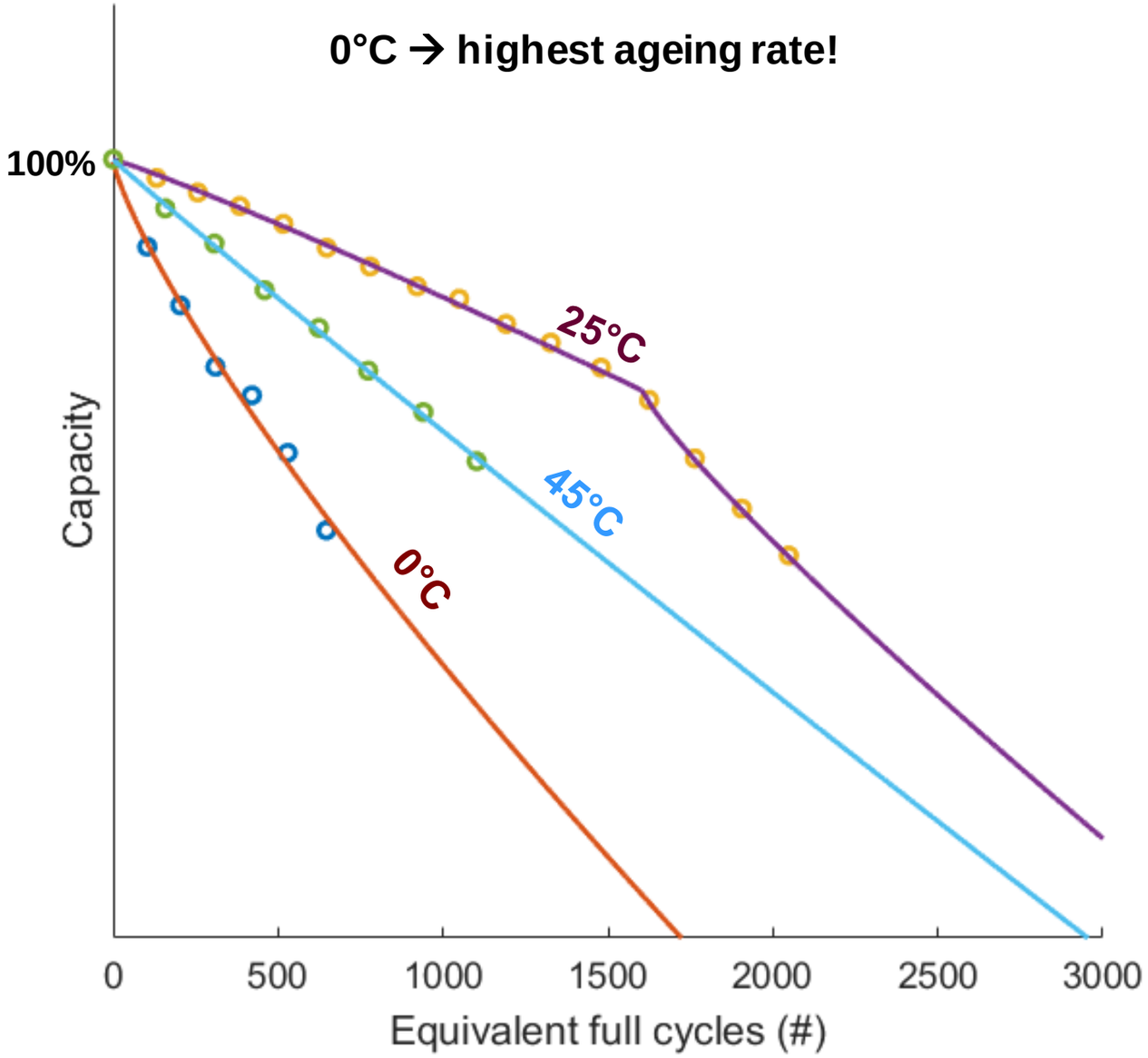


Waldmann *et al* DOI: 10.1149/2.0961713jes

Why is Li-plating bad?



Li-metal becomes electrically disconnected
Can not be discharged → **capacity loss**



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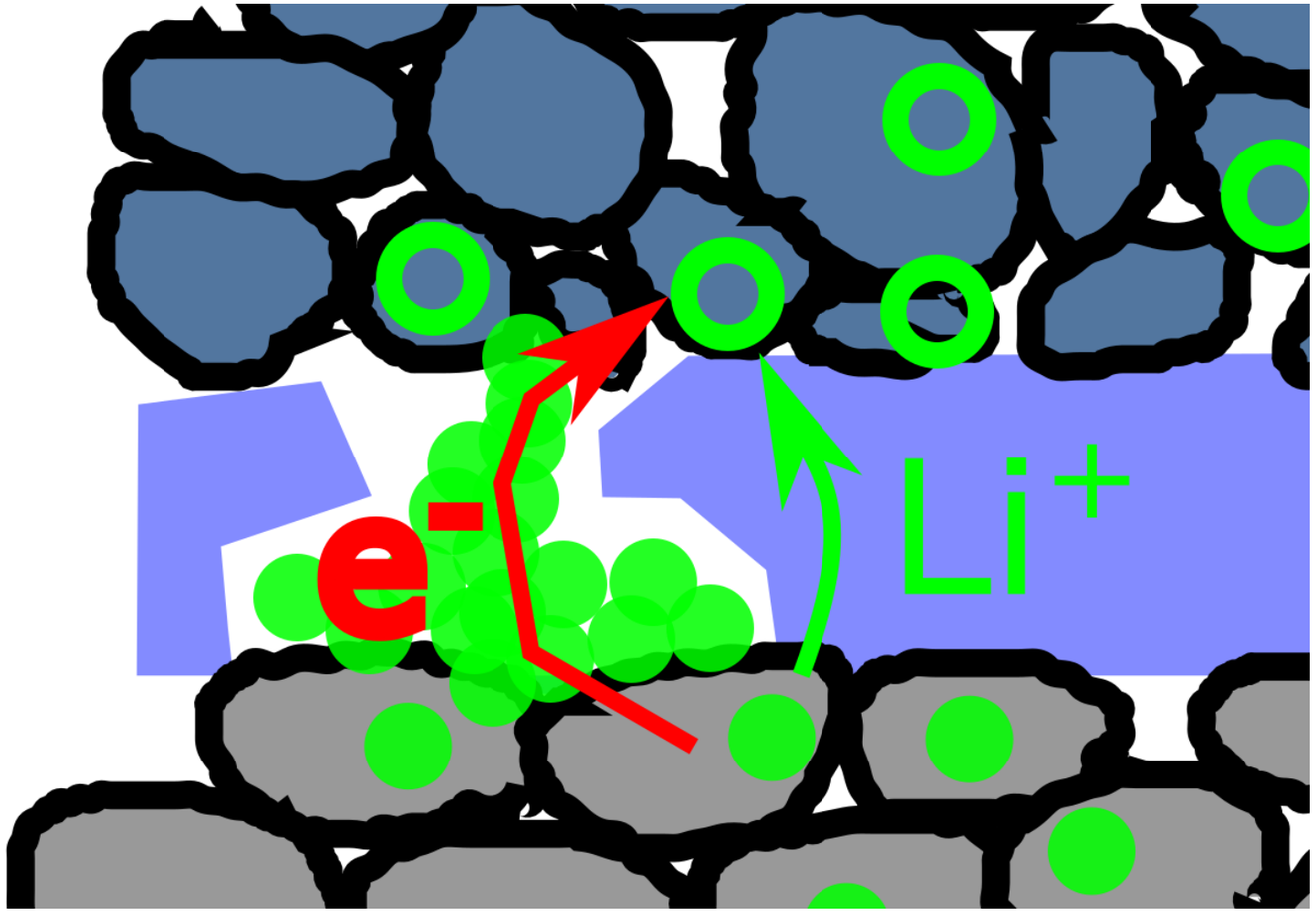
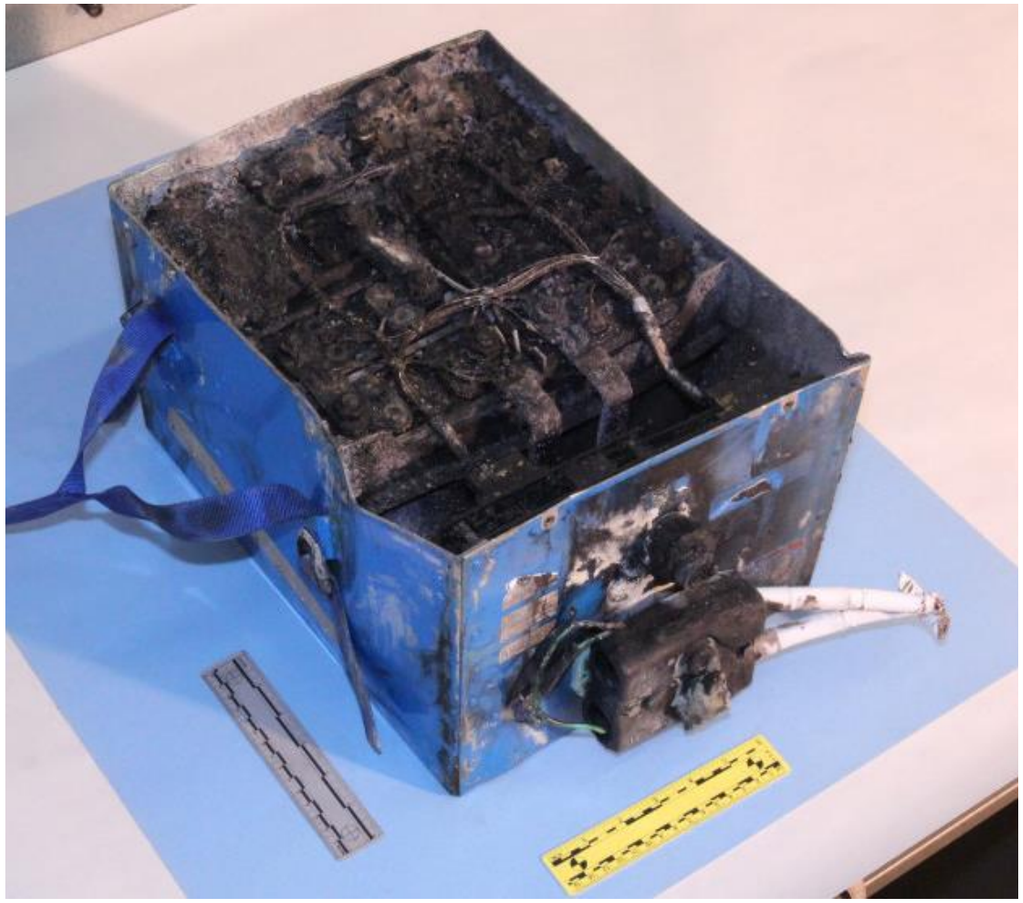
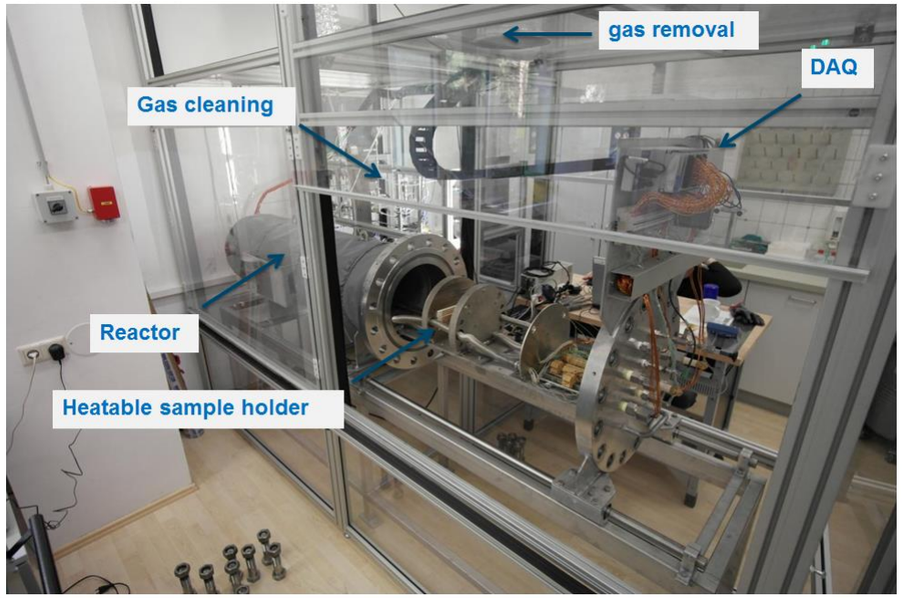


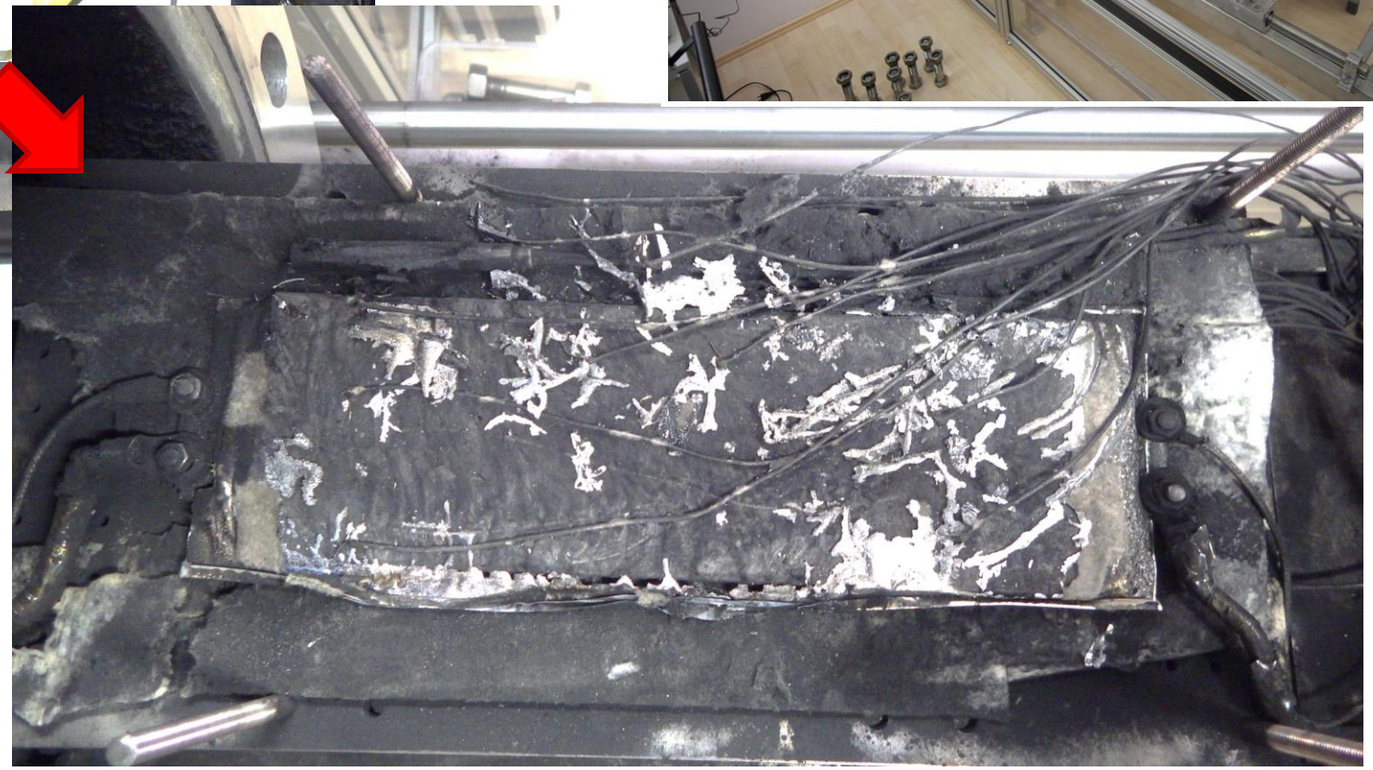


Can damage separator → internal short
Self discharge → **heat up**
Can develop into thermal ruanway

Boeing dreamliner battery after thermal runaway

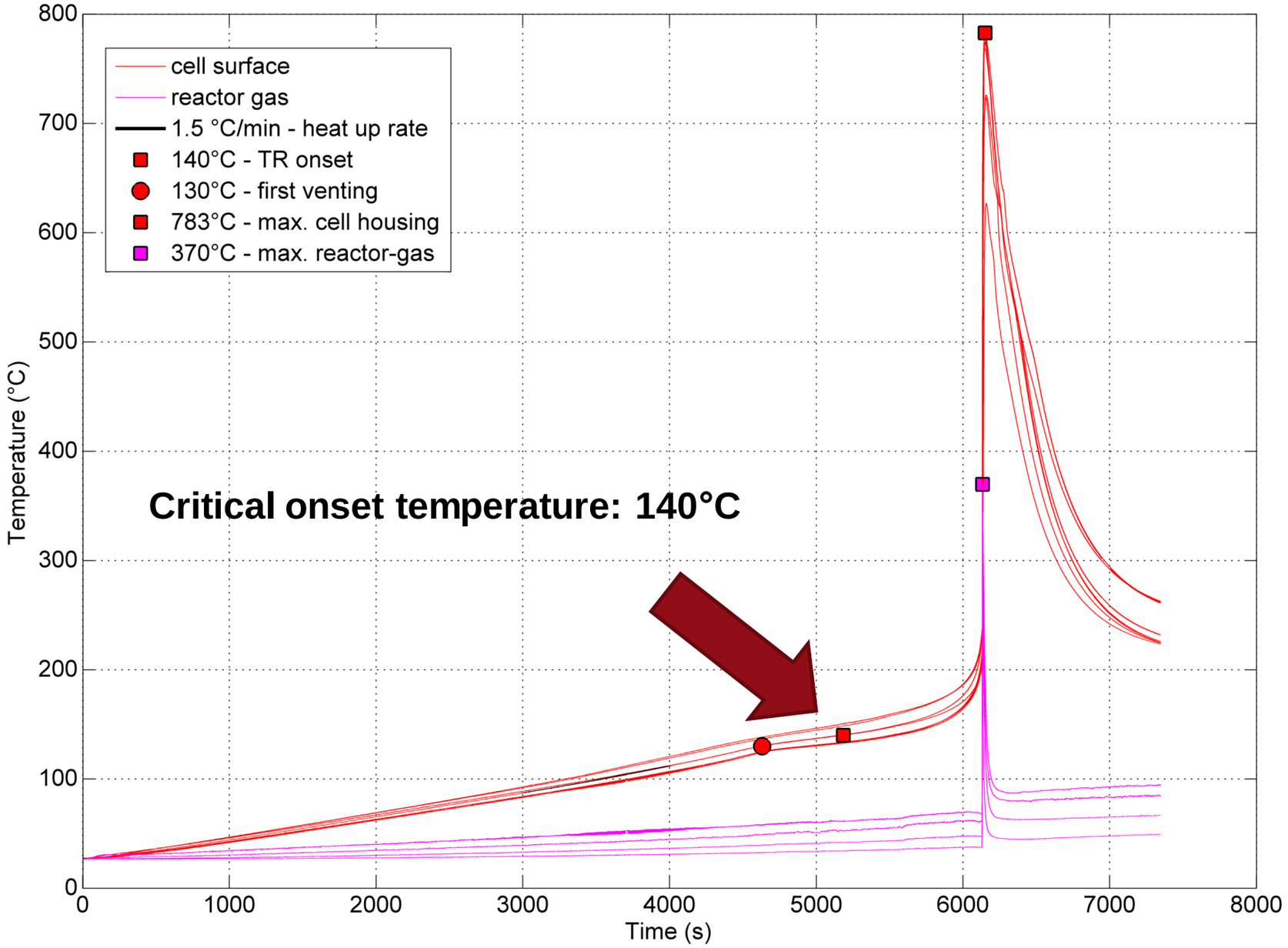
Thermal Runaway of a cell

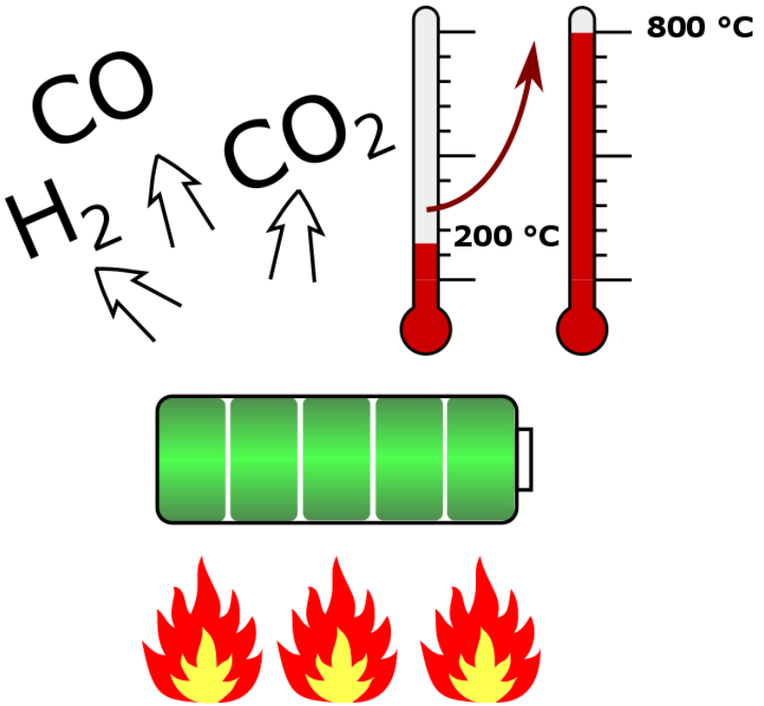




Results from tests in the thermal runaway laboratory at Virtual Vehicle

Typical experiment results





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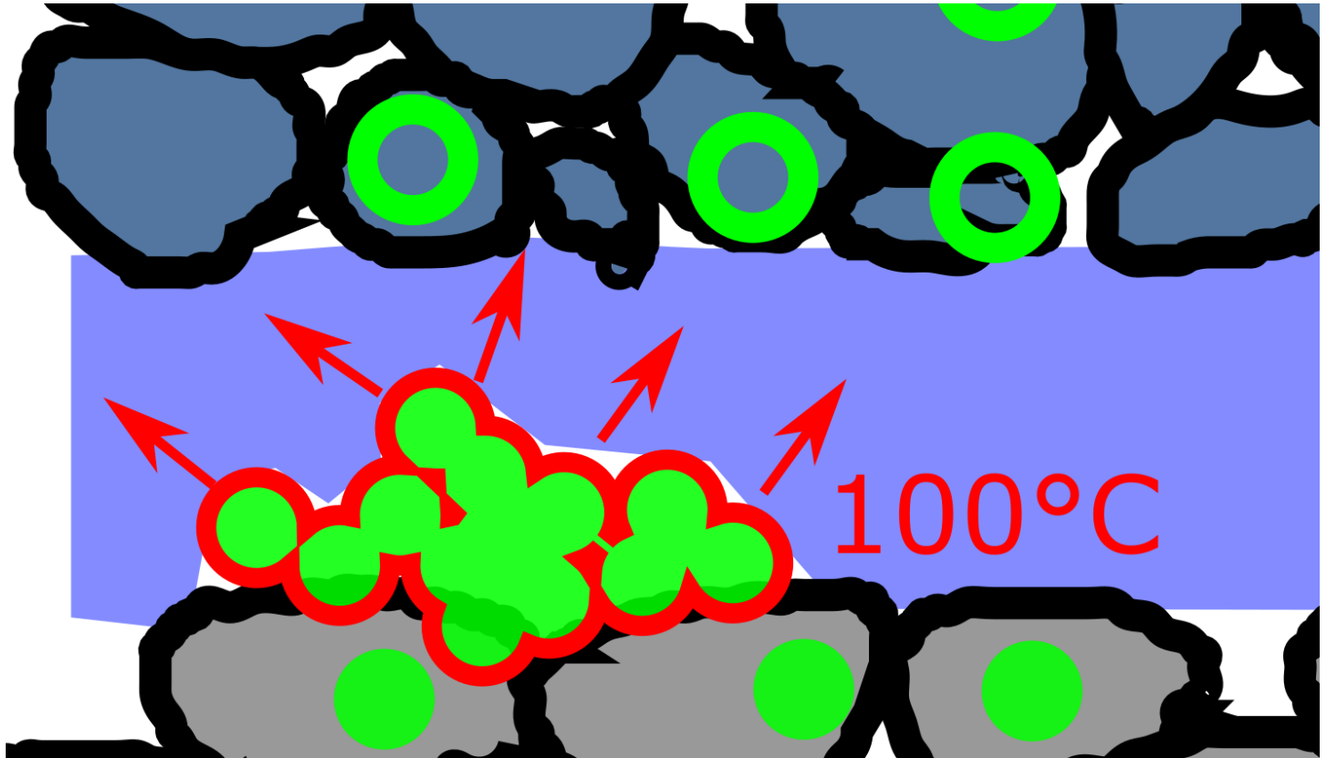

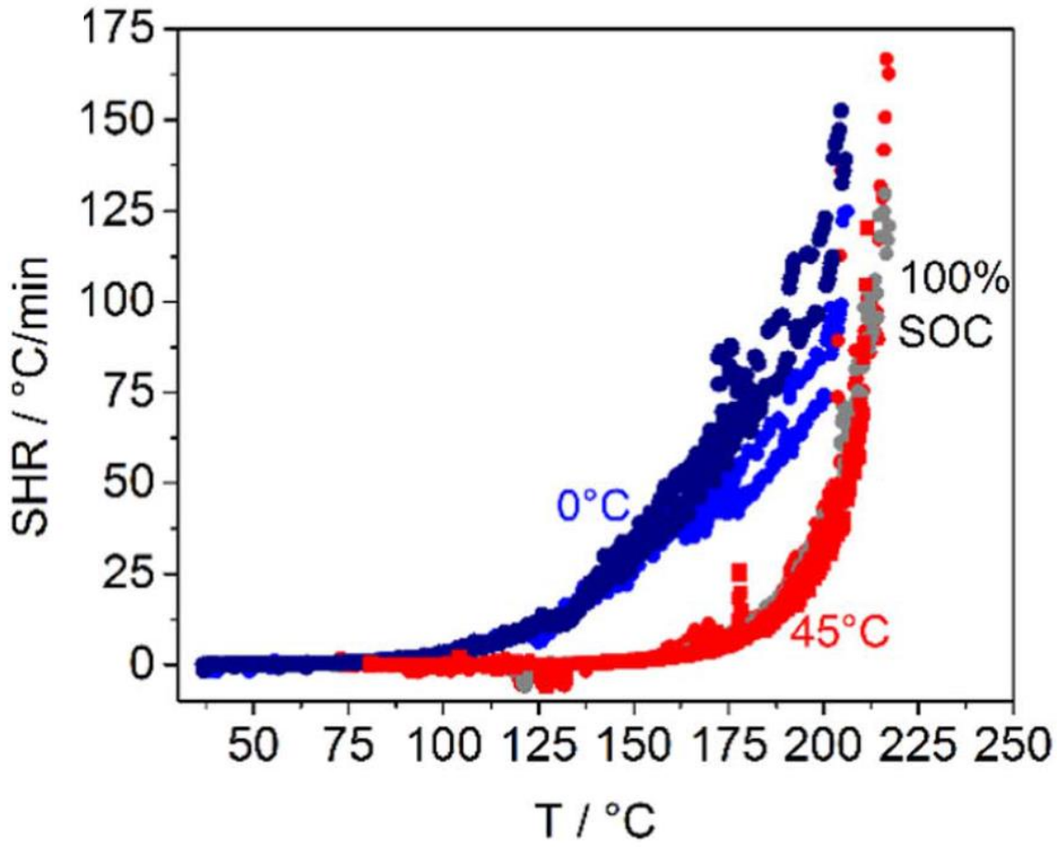

If heated above 100°C → metalic-lithium starts to react
Promotes further heating → earlier thermal runaway

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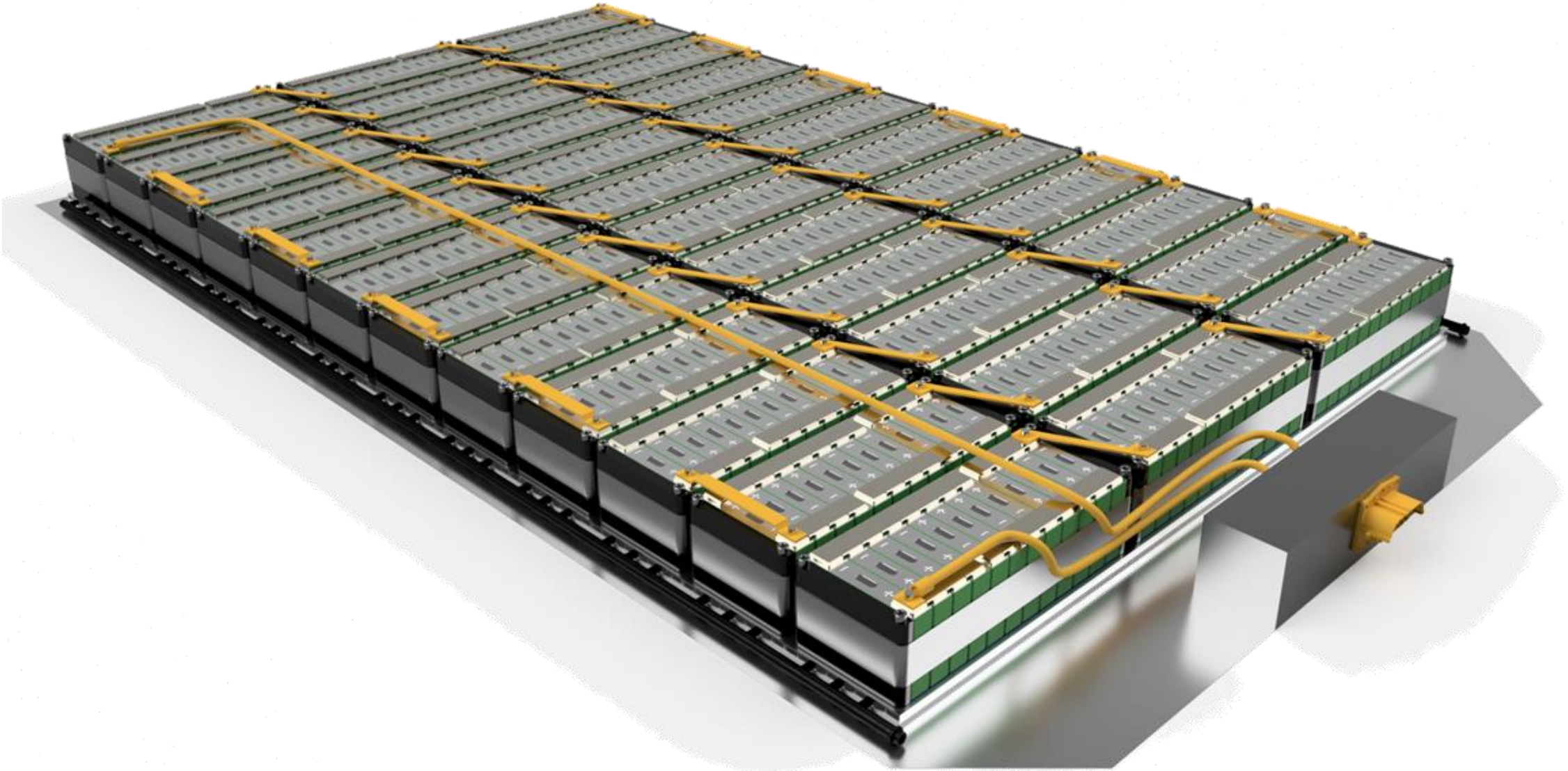
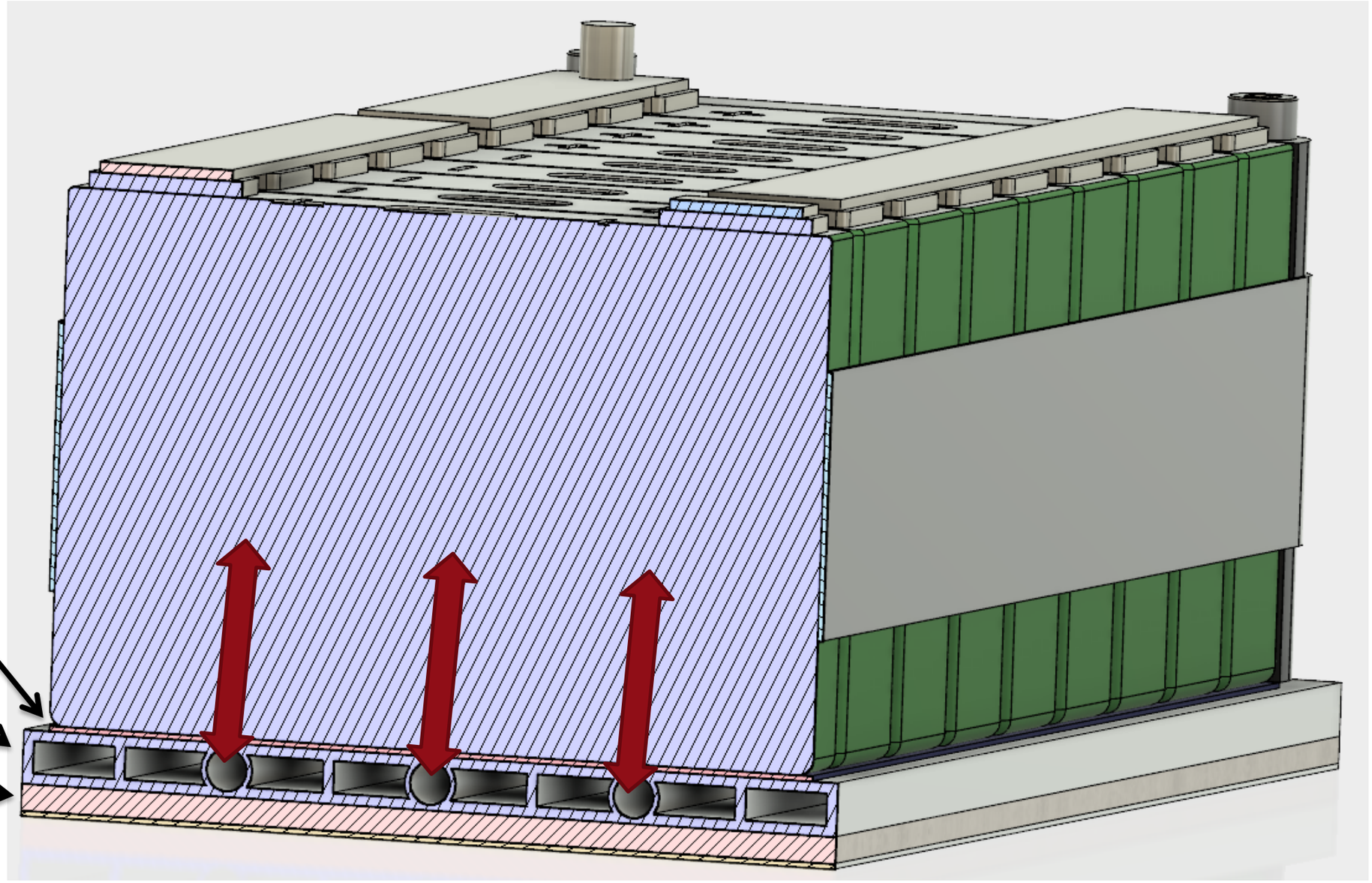
Battery pack for EV



Conventional design



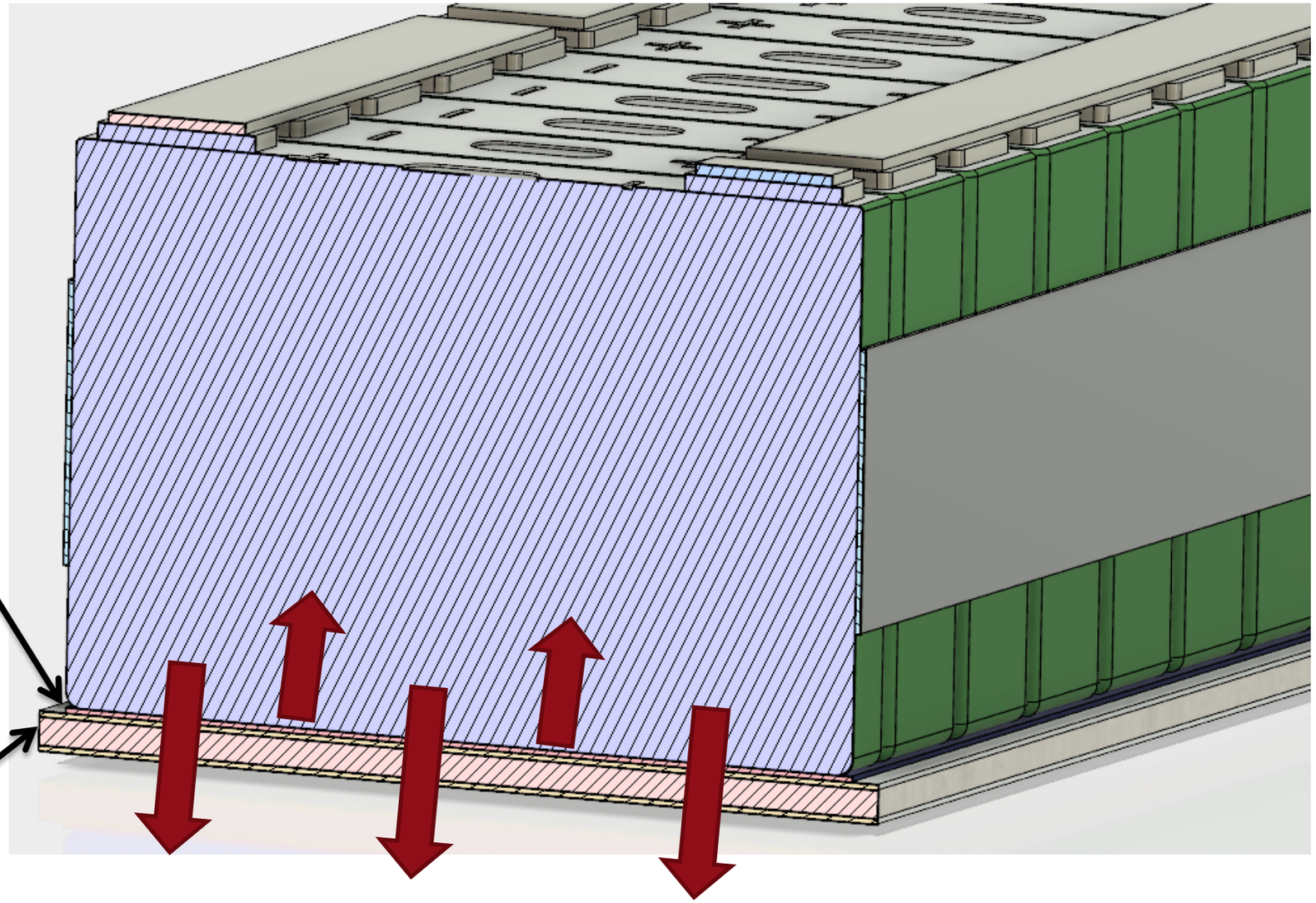
Concepts

Thermal pad + electric heating foil

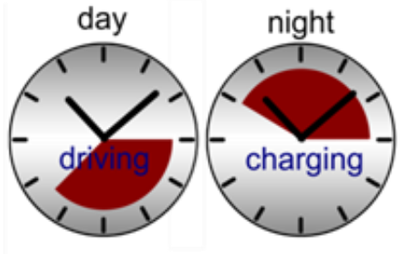
Thermal interlayer

Adjustable heat condunctivity

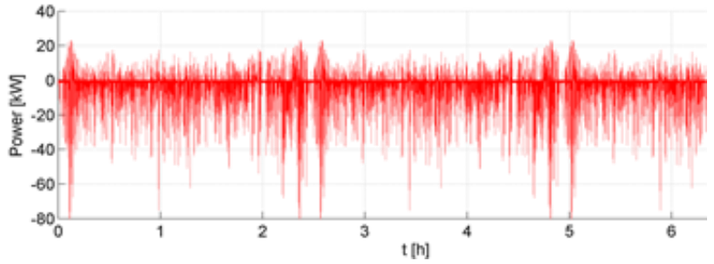
- **Put in / remove gases / liquids with different heat conductivity**
- **Compress / expand thickness**



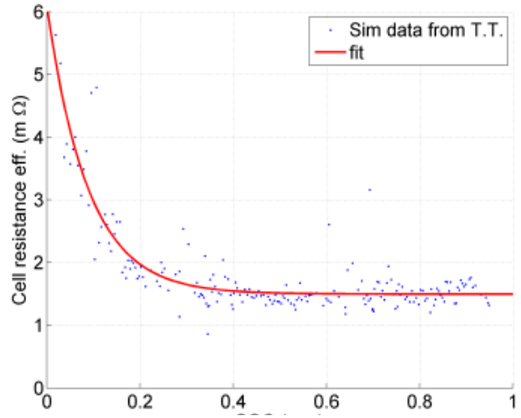
Ageing simulation framework



7 days per week

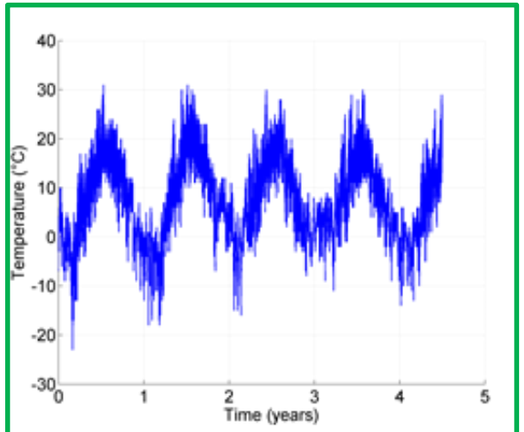


driving cycle

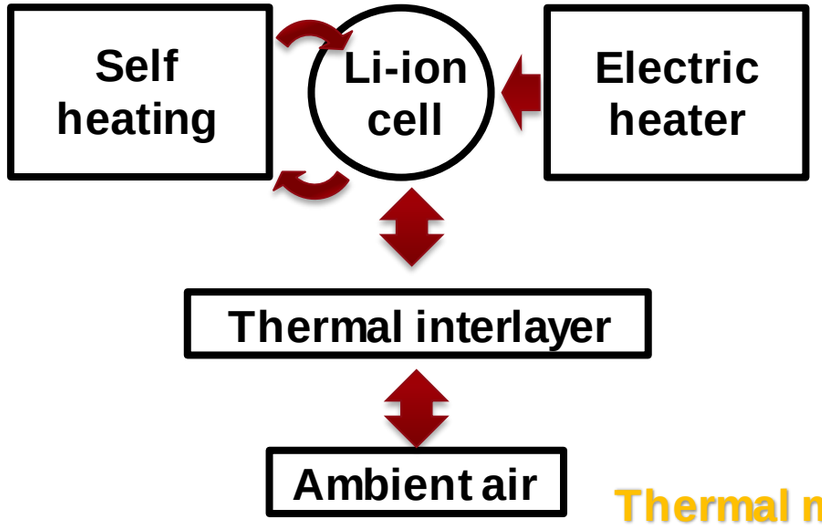


Cell characteristics

Cooling/ heating strategy

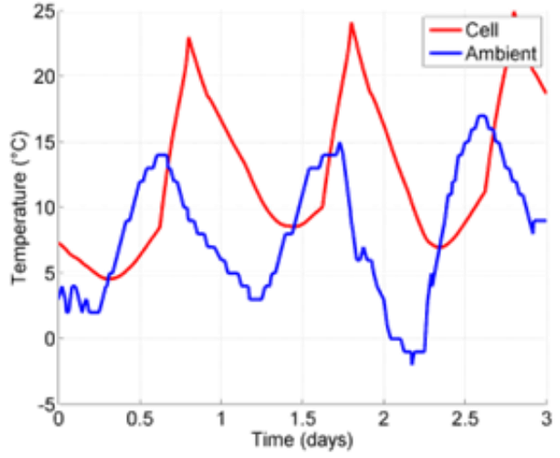


Ambient temperature-data (2000 – present)



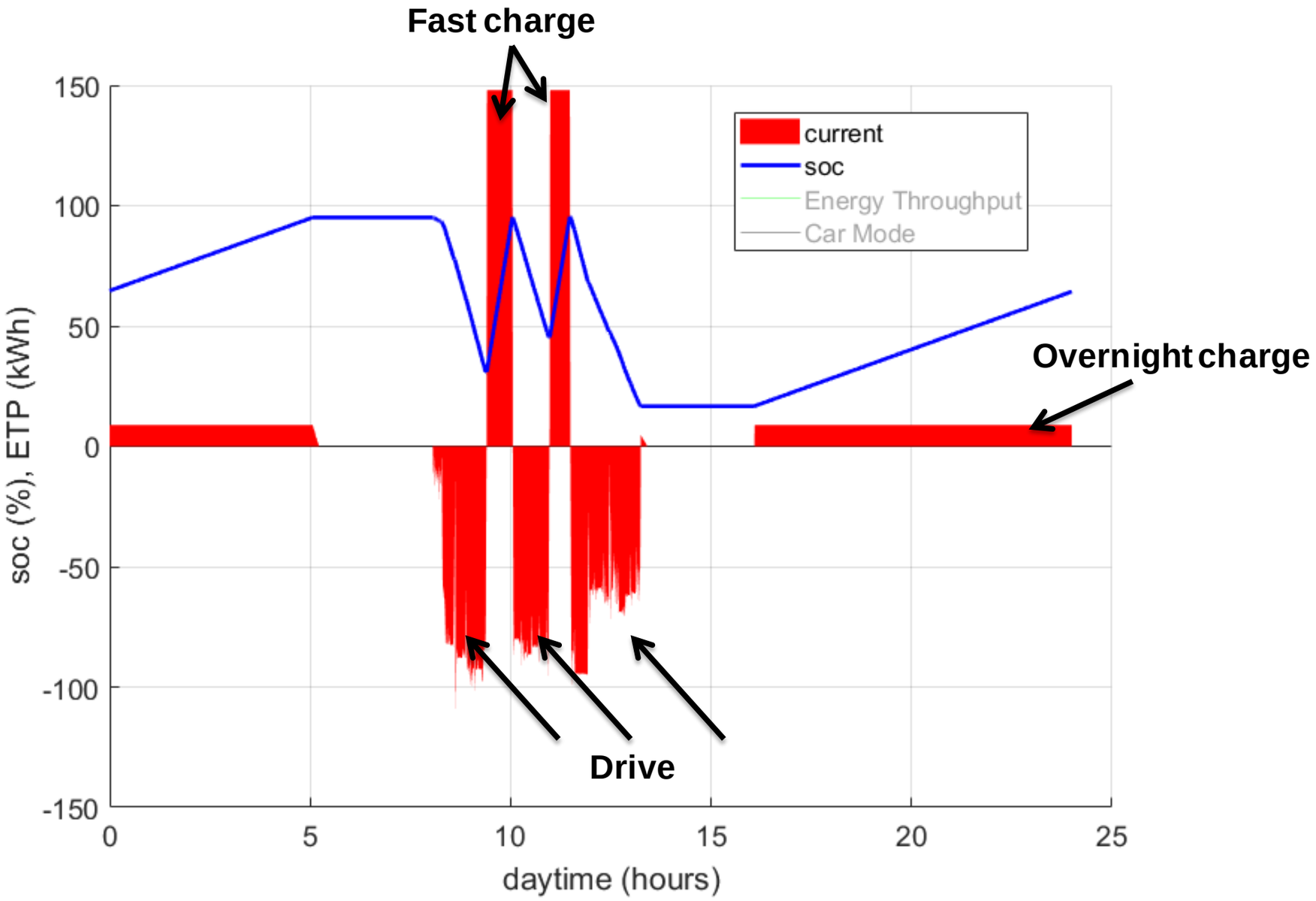
Thermal model

Temperature (and SOC) dependend:
- **Aging**
- **Available power (usability)**

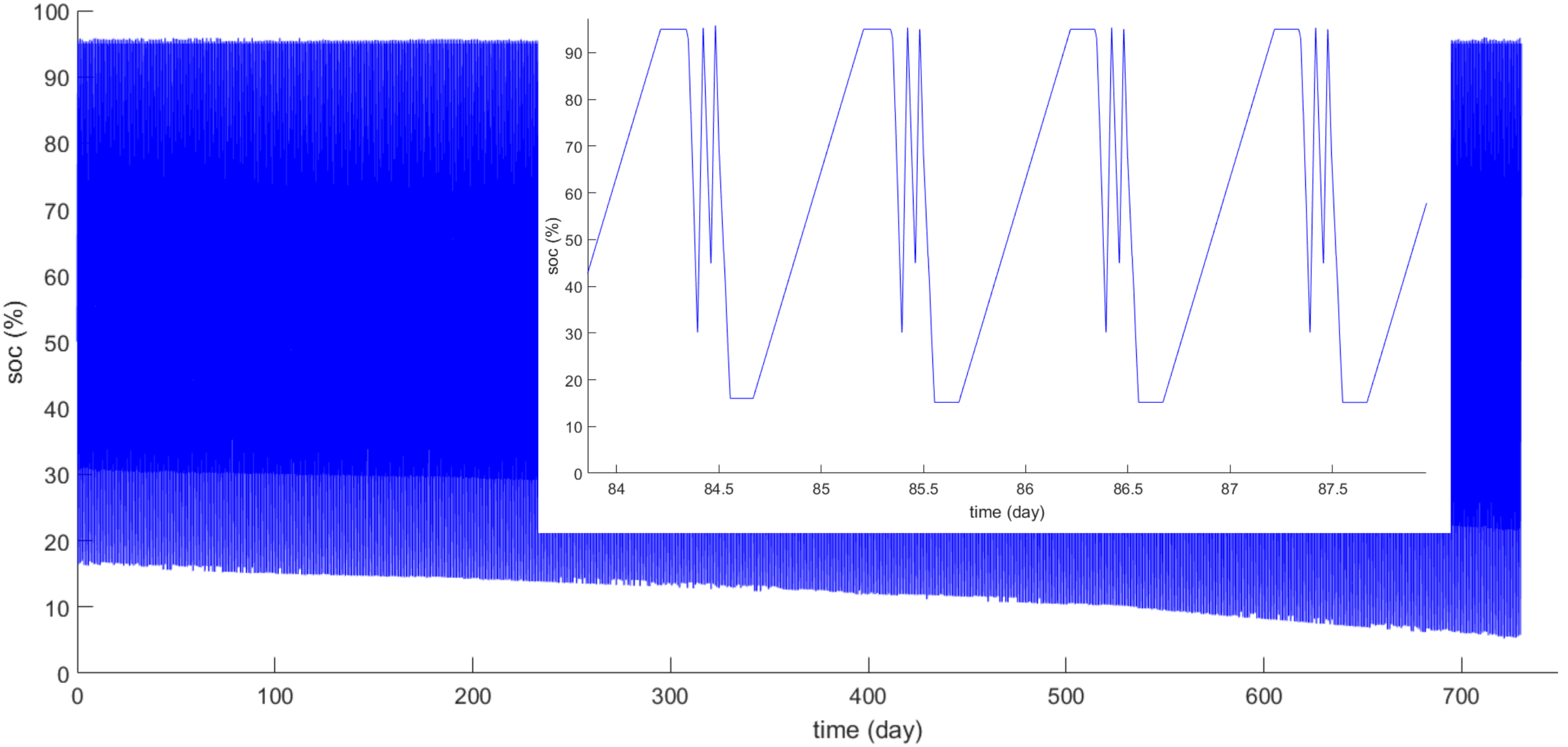


Battery temperature and SOC timeseries

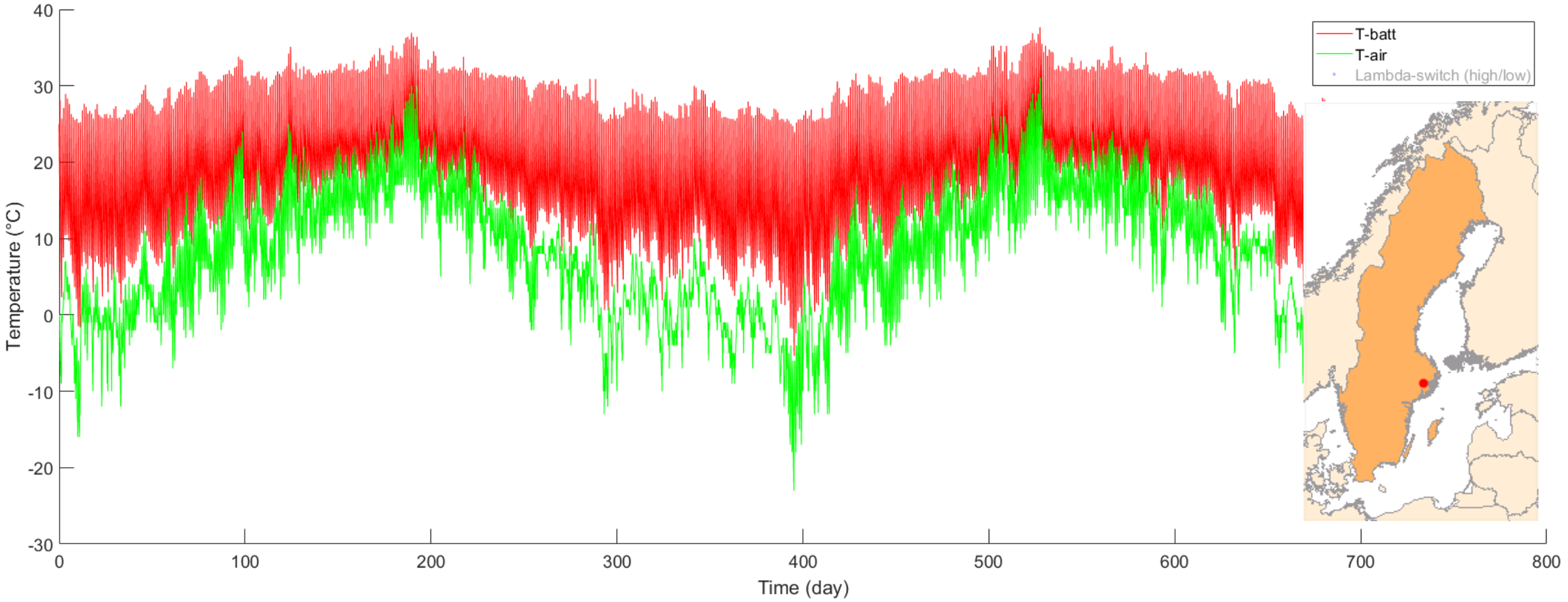
Simulated driving cycle



Simulate 2 years with challenging cycle

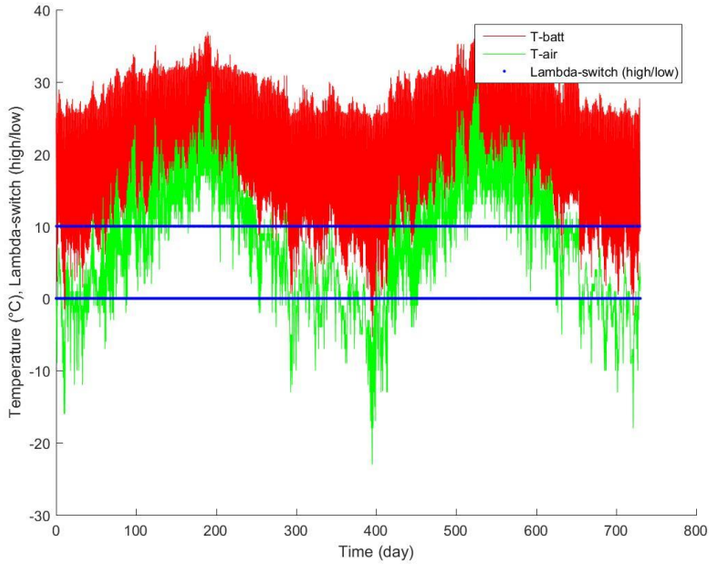


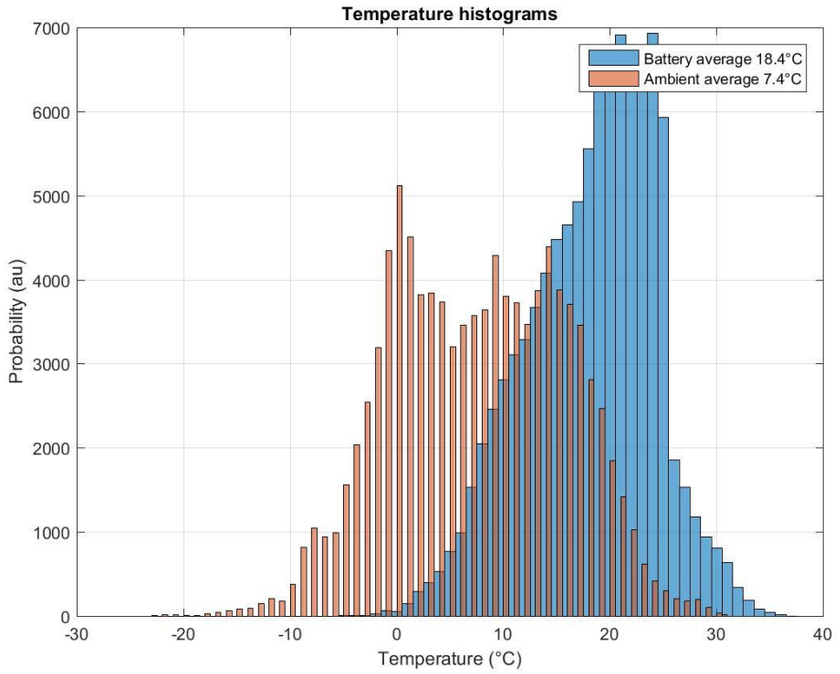
Cell / ambient temperature

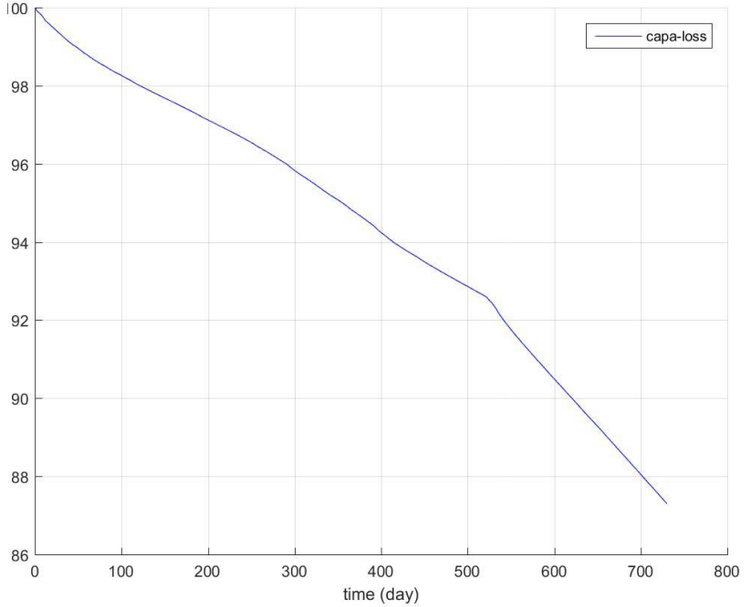


Simulated scenarios

Scenario Nr	Dual Lambda (switch tempoerature)	Heating (setpoint temperature)	Capacity loss %	AVG. Battery temperature	AVG. Air temperature	Energy for battery heating kWh/year
1	25°C		12,69	18,4	7,4	0
2			16,18	12,5	7,4	0
3		5°C	15,95	13,3	7,4	110
4		10°C	15,44	14,6	7,4	281
5		15°C	14,34	16,4	7,4	538
6		20°C	12,64	18,8	7,4	877







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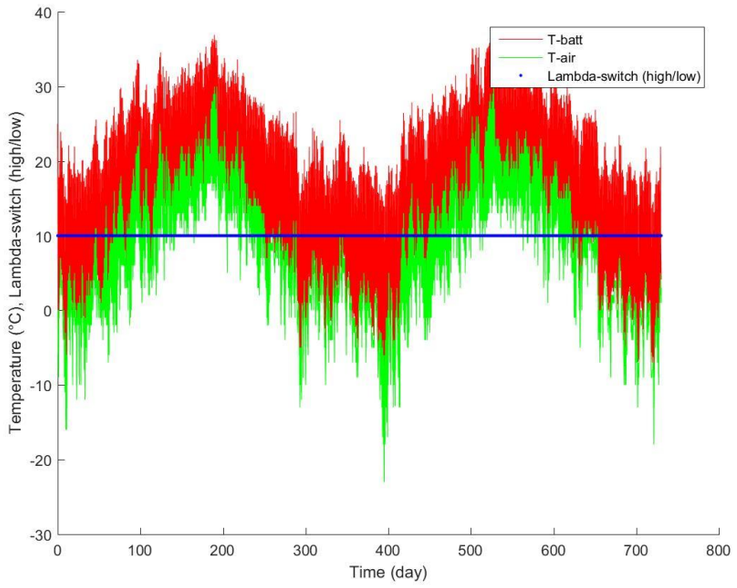

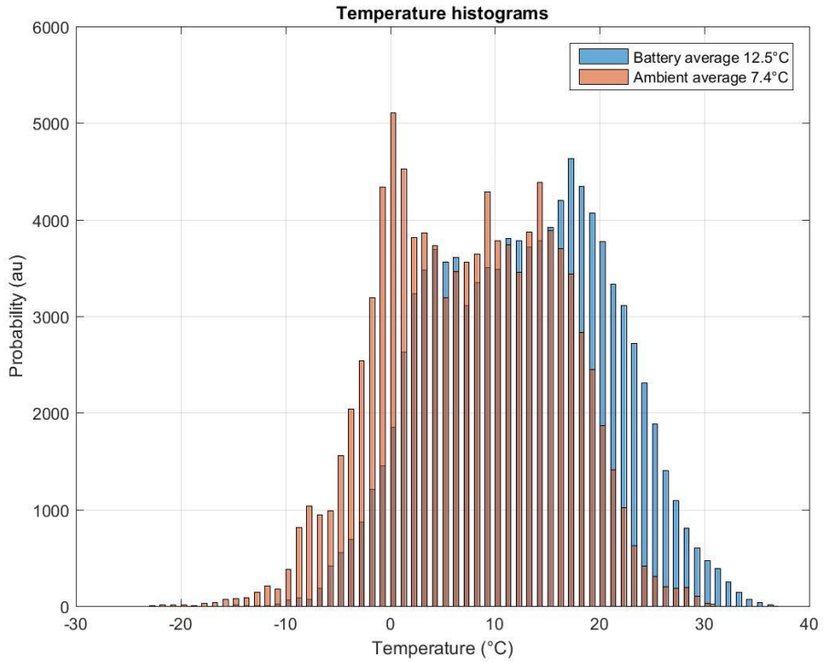

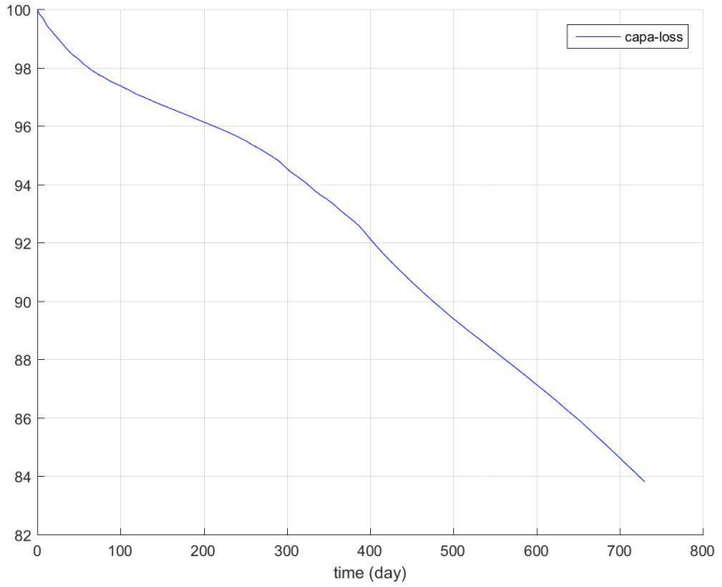

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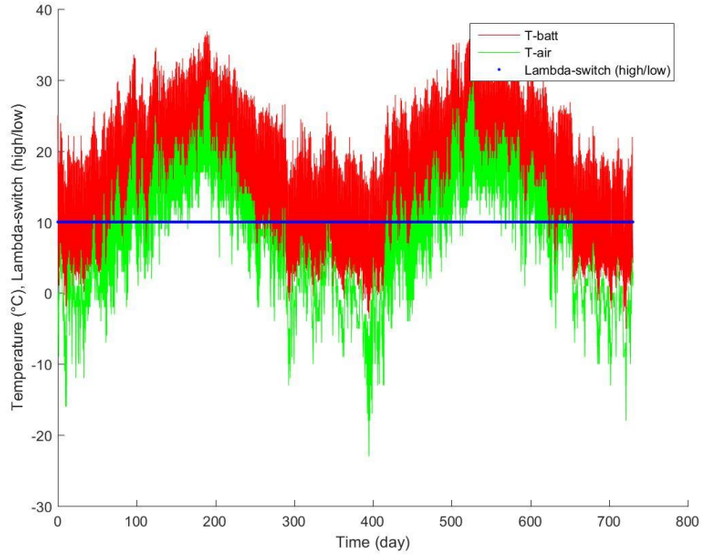

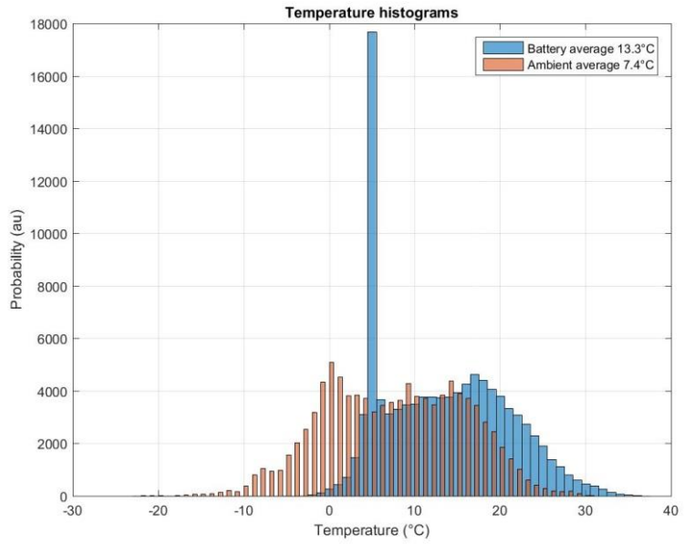

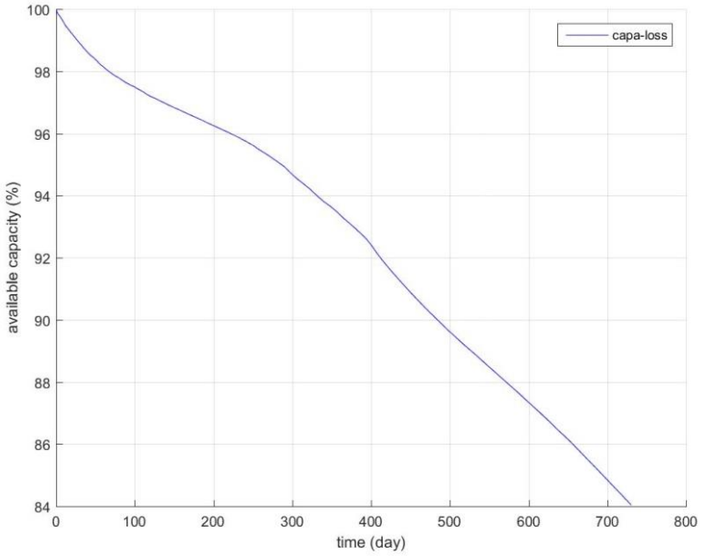

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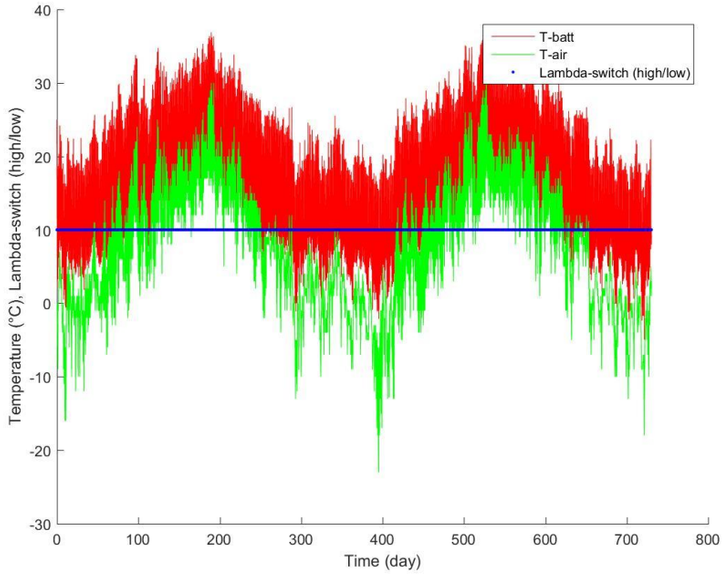

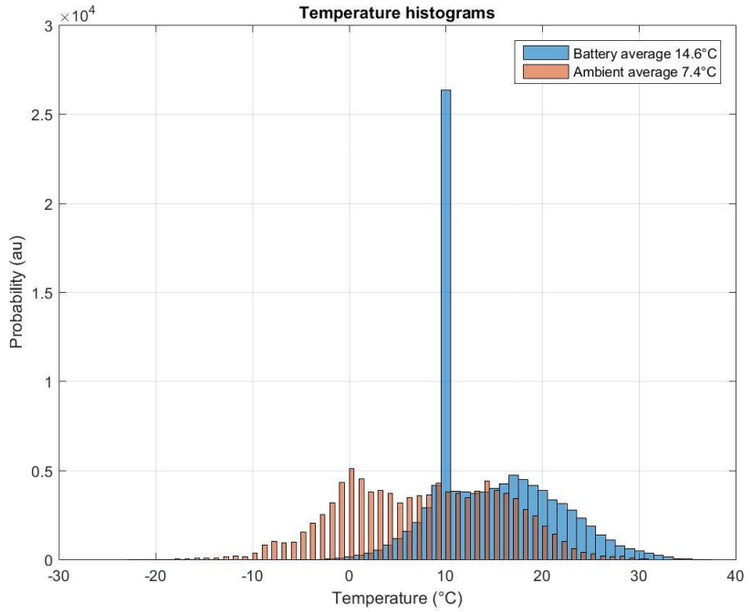

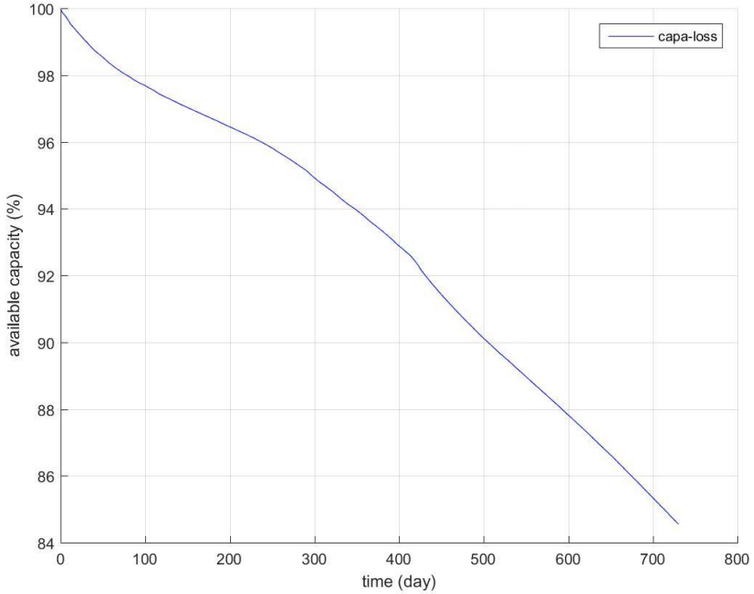

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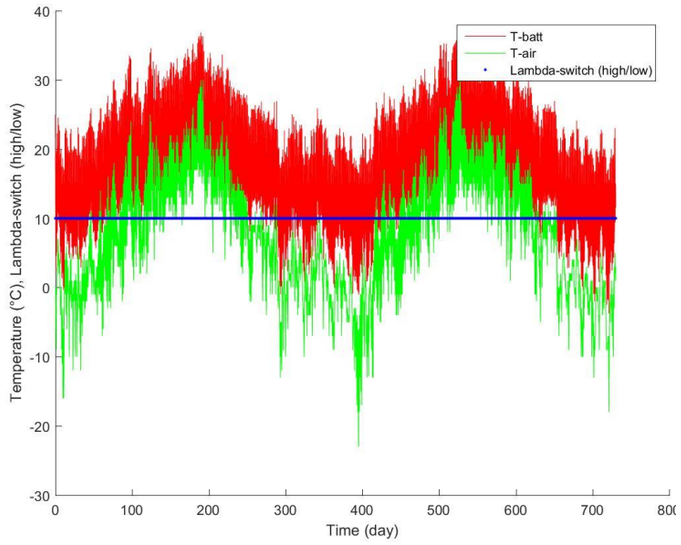
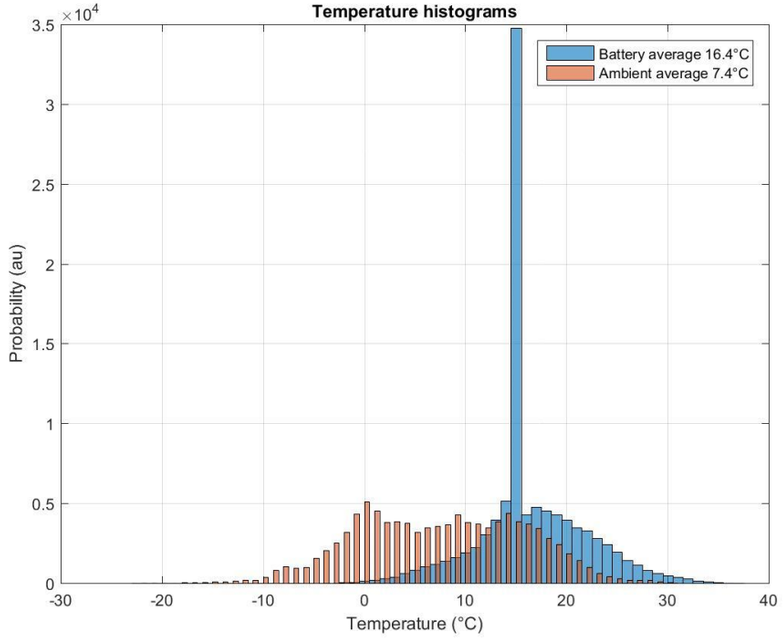
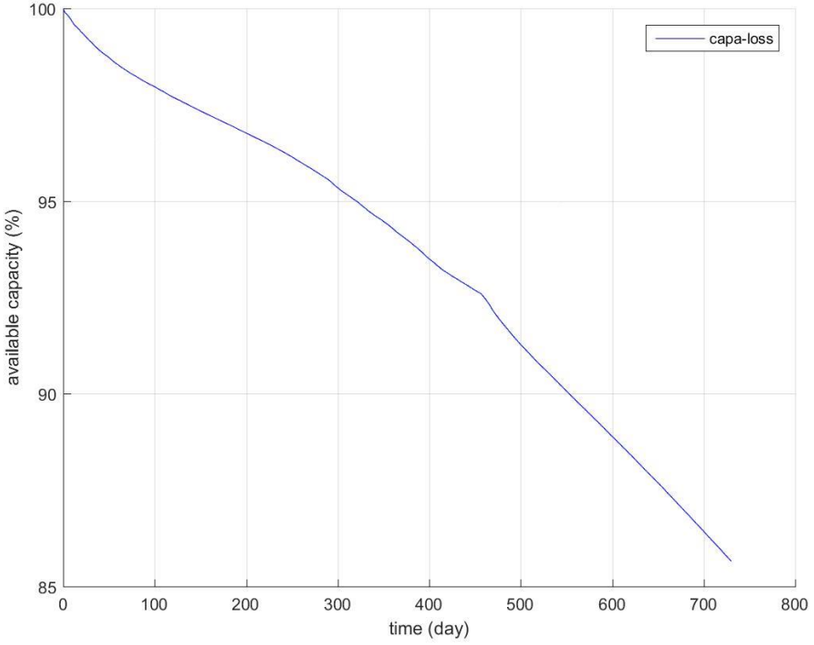
6		20°C	12,64	18,8	7,4	877

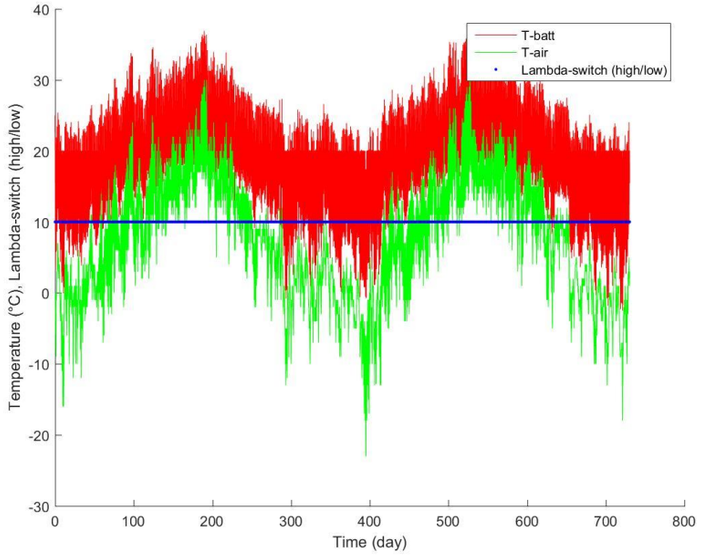


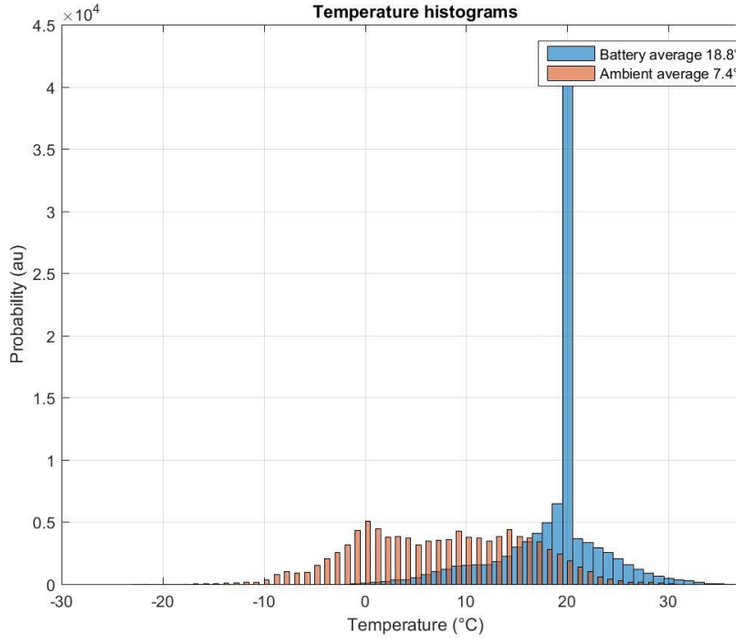


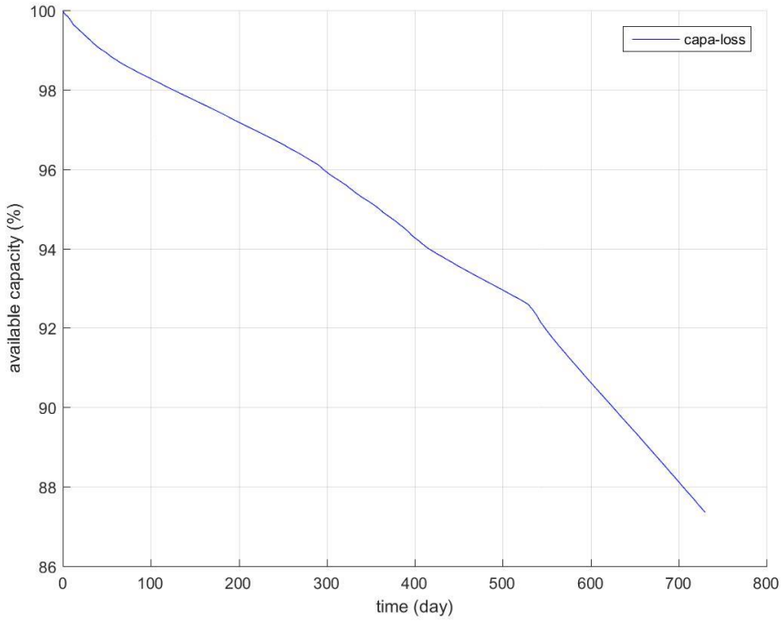


Simulated scenarios

Scenario Nr	Dual Lambda (switch tempoerature)	Heating (setpoint temperature)	Capacity loss %	AVG. Battery temperature	AVG. Air temperature	Energy for battery heating kWh/year
1	25°C		12,69	18,4	7,4	0
2			16,18	12,5	7,4	0
3		5°C	15,95	13,3	7,4	110
4		10°C	15,44	14,6	7,4	281
5		15°C	14,34	16,4	7,4	538
6		20°C	12,64	18,8	7,4	877







Conclusion

Li-ion batteries need temperature > 10°C for fast charge

Need complicated thermal management for cold climate

Alternatives are

- **Thermal interlayer with adjustable heat conductivity**
- **Heating foil**

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bmwfw Bundesministerium für Wissenschaft, Forschung und Wirtschaft
FFG
COMET Competence Centers for Excellent Technologies
Das Land Steiermark
SFG
TU Graz Graz University of Technology