TESTING AND EVALUATING THERMAL PERFORMANCE OF BATTERY SYSTEMS

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www.ise.fraunhofer.de

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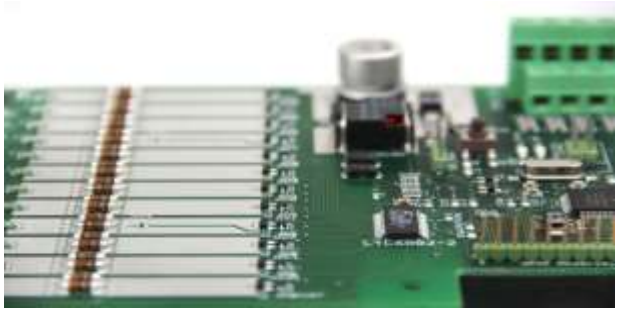
AGENDA

- Introduction ISE – Lab Batteries
- Thermal Management
- Using a Calorimeter
- Results and Discussion
- Context and calculation
- Verification of results
- Significance for applications




Group
Battery Engineering

- Battery testing
- Development of battery systems
- Development of electronics and software for battery management
- Battery monitoring
- State of charge estimation
- State of health estimation (capacity)
- Charging and operating control strategies
- Concepts for safety
- Modeling and simulation
- Technical and economical system analyses (e.g. life cycle cost)
- Main focus: lithium-ion, lead-acid, redox-flow



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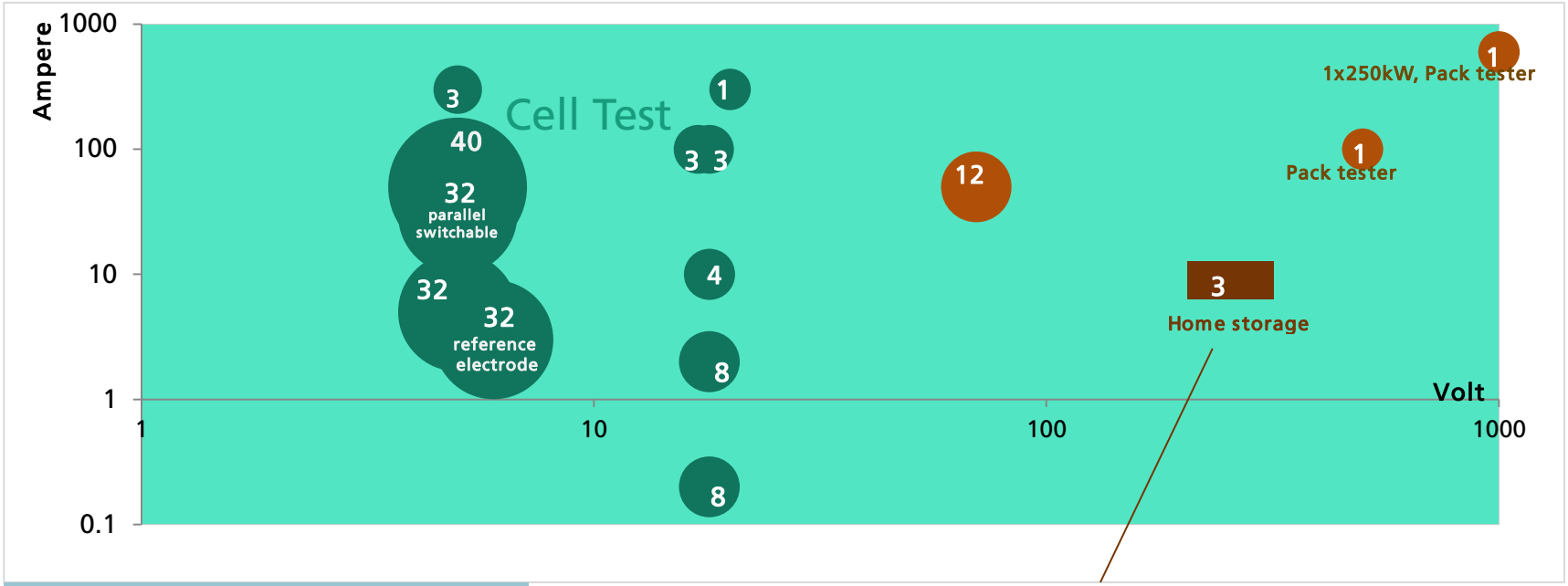
ServiceLab Batteries - Fraunhofer ISE



Additional:

- 4 channels impedance spectroscopy 1µHz – 4,5kHz
- 14 Climate and temperature chambers
- Glovebox
- Battery calorimeter

➔ 193 test circuits

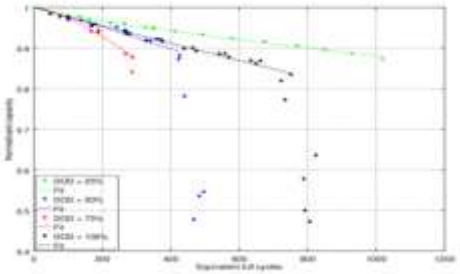
Battery Technology

Ageing investigation of lithium-ion cells

Research Question

Ageing characterization and life time prediction based on calendar and cycle life test

- Cell characterization by applying Ageing, Performance and Safety tests
- Characterization with 190 + test circuits
- Parametrization of ageing depended battery models
- Post Mortem Analysis of cells
- Ageing prediction depending on load an temperature profile



Fresh linear non-linear aging stage

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Product Design and Implementation
Consulting and certification

Research Question

How to ensure safety and quality of battery systems in mobile and stationary application

- Strategic partnership between VDE and ISE
- Seamless support from product design to Implementation
- Feasibility study and simulation
- Certification of products and installations

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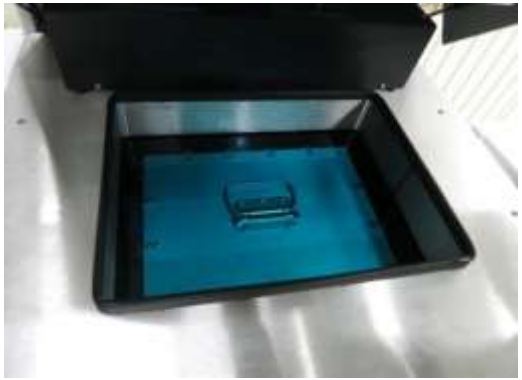
Thermal Management - Battery

- Goal
  - Strategy for cooling and heating of the battery system, to
    - raise the efficiency of the system
    - while reducing battery ageing
- Methods
  - Cell selection
  - Environmental factors (temperature, systemsize, load profile)
  - Cell properties (performance, ageing)
  - Dimensions of cooling and heating system, including thermal connections
  - Definition of parameters (nominal values, soft and hard limits) and strategies (preconditioning)
  - simulation / test / implementation / monitoring

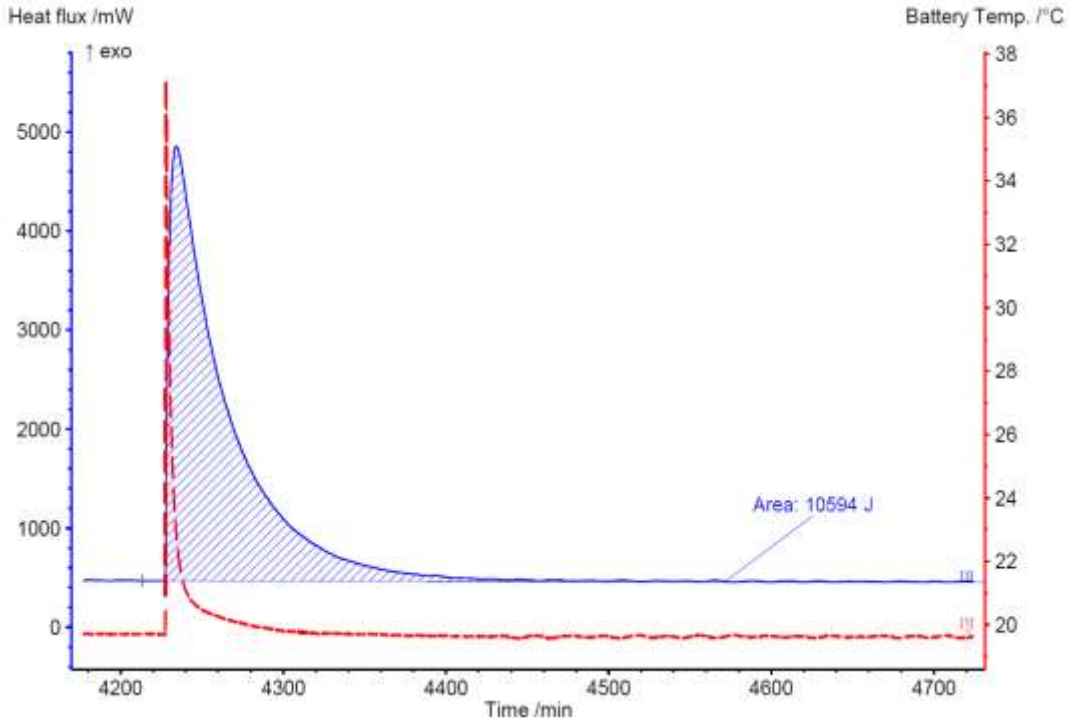
Isothermal Calorimeter

[www.netzsch-thermal-analysis.com]



Isothermal Calorimeter

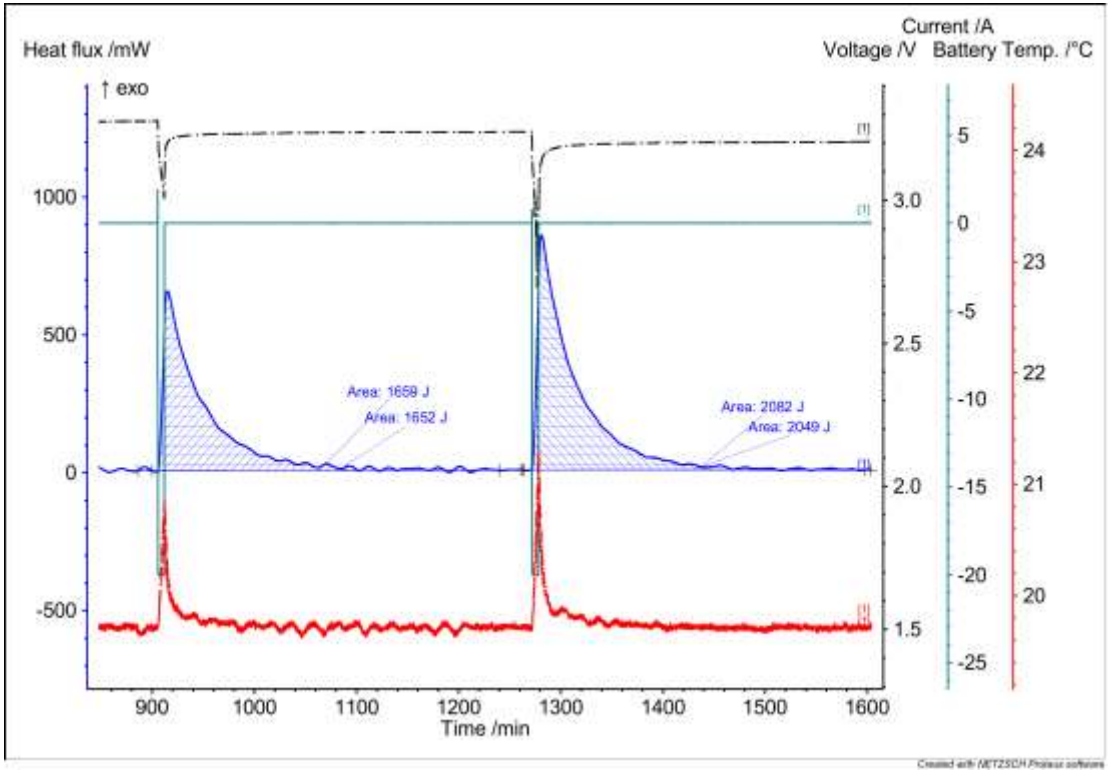
- Q = 10˙594 J
- dT = 40°C – 20°C = 20 K
- m = 493 g
- $c_{p\ bat}$ = 1˙074 $Jkg^{-1}K^{-1}$
  - Water = 4˙182 $Jkg^{-1}K^{-1}$
  - Iron = 452 $Jkg^{-1}K^{-1}$
  - Concrete = 880 $Jkg^{-1}K^{-1}$



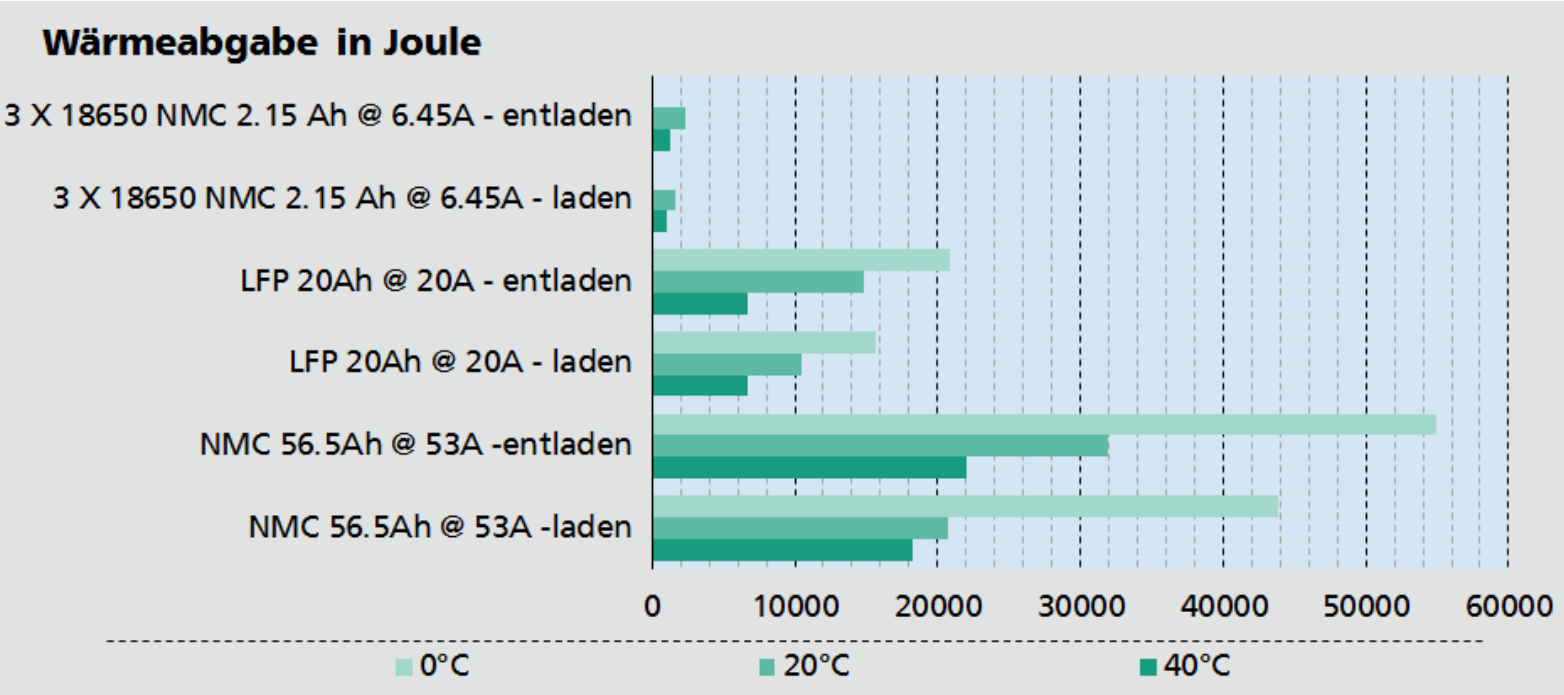
Isothermal Calorimeter

- 2x -1C for 6 min.
- 20 Ah LFP

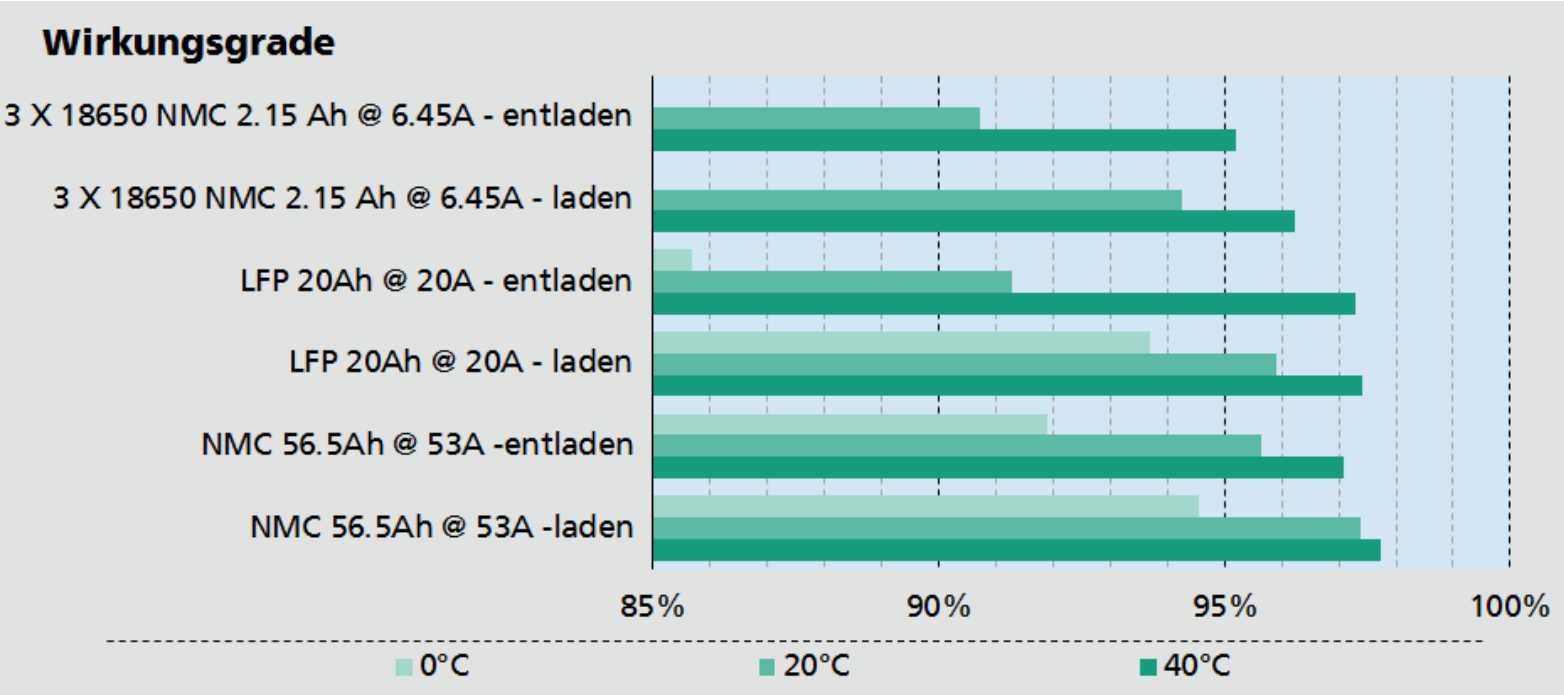
[www.a123systems.com]



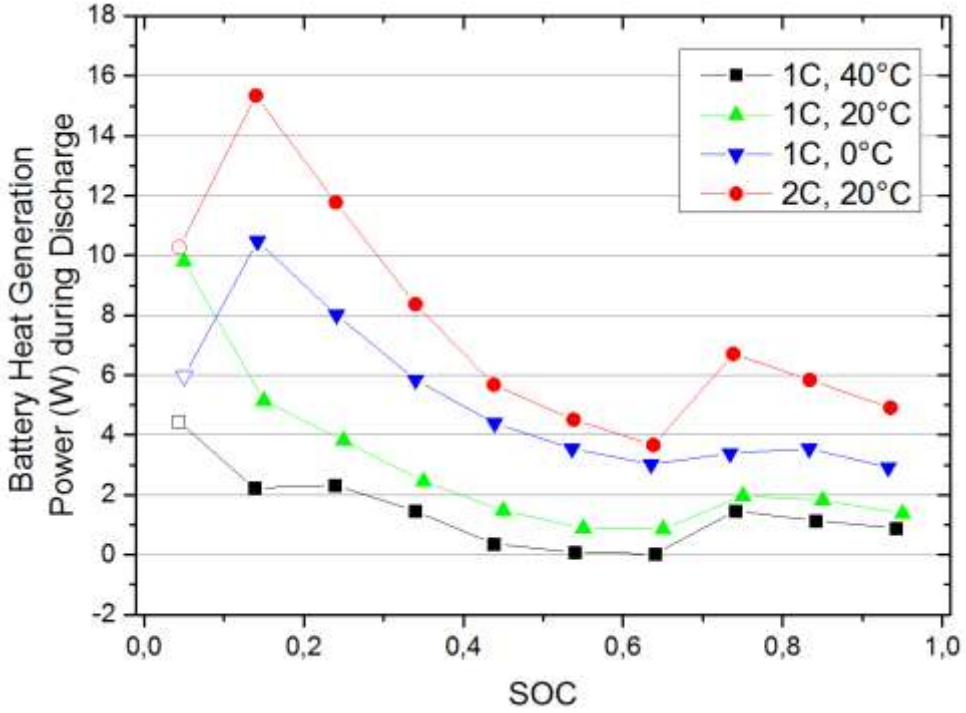
Results and Discussion – heat generation [J]

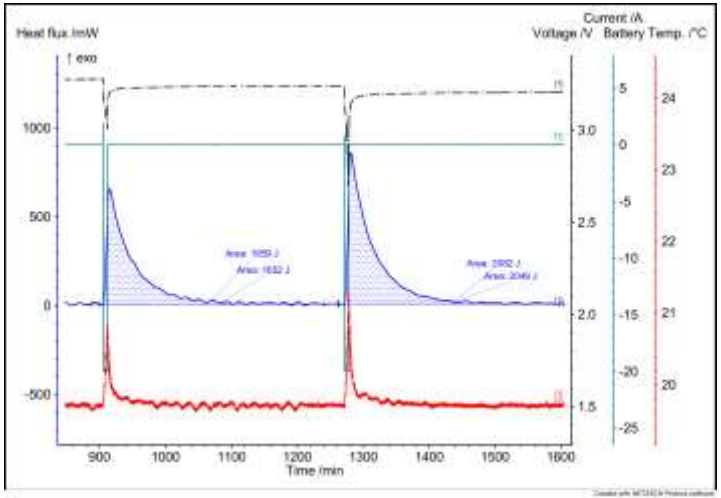


Results and Discussion – energy efficiency



Results and Discussion





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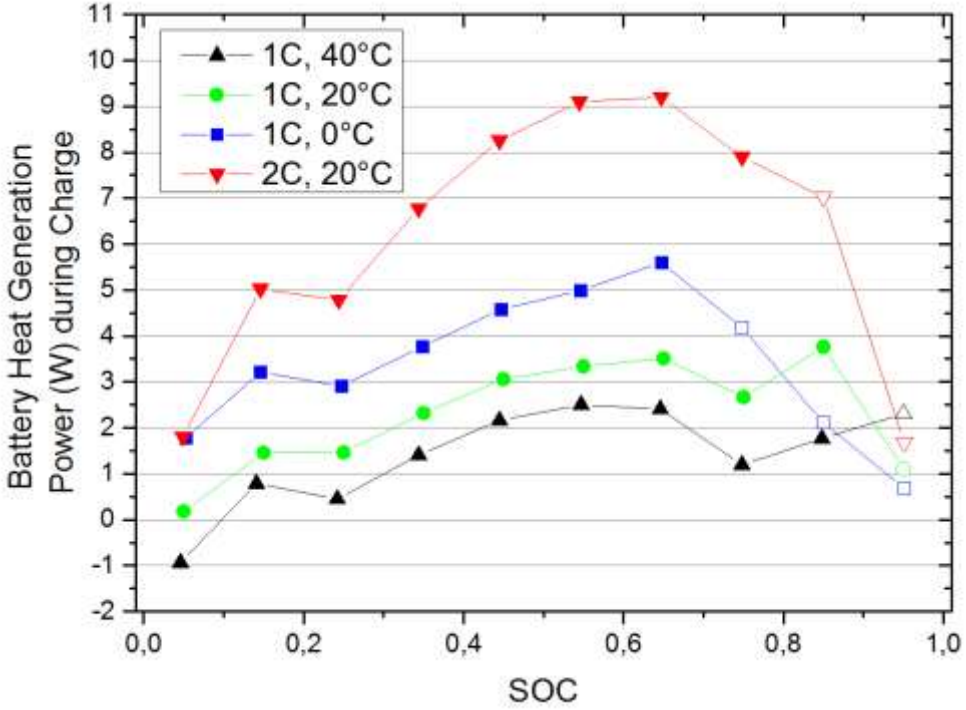
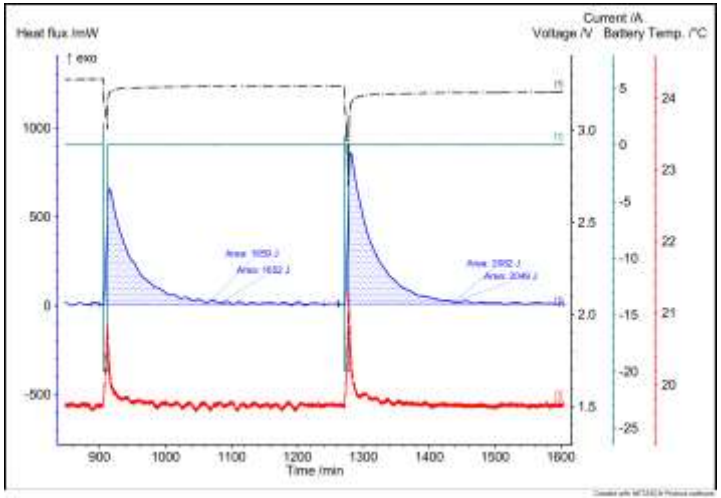
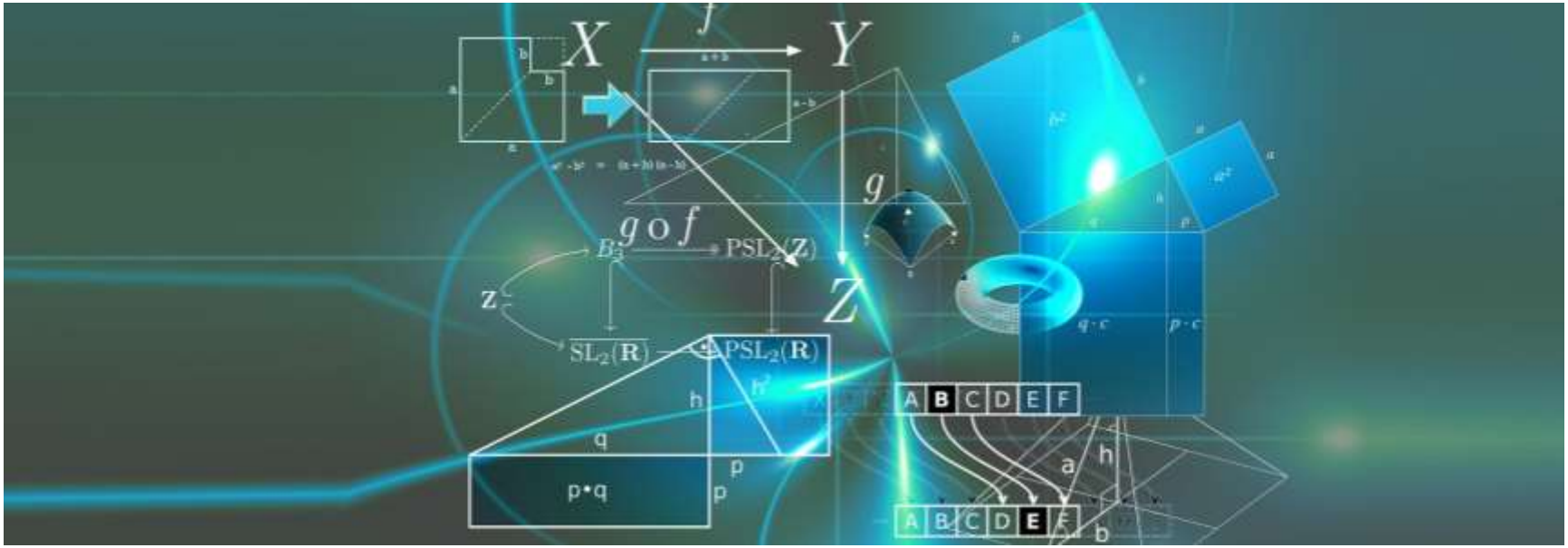




Context and calculation



Context and Calculation

- Bernadi's et. al. formula:

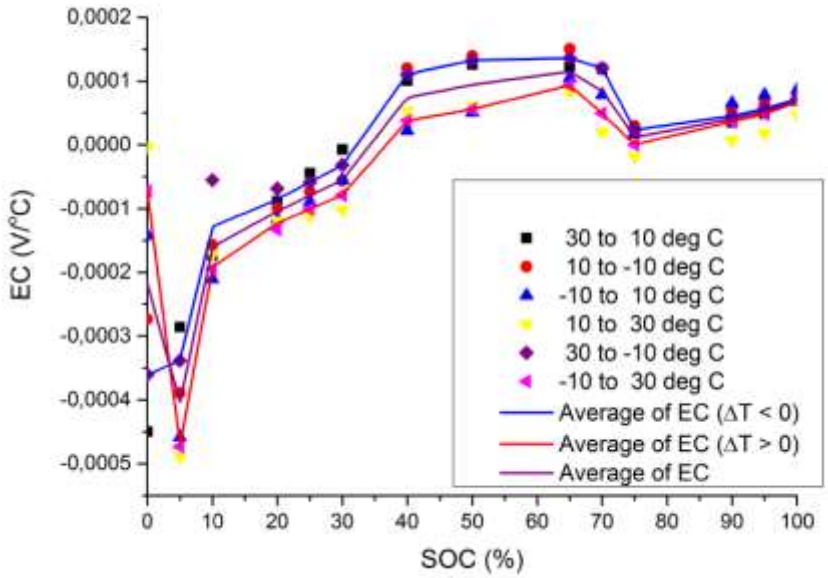
$$q_{gen} = I \cdot \Delta U + I \cdot T \cdot \frac{dU}{dT} \quad [W]$$

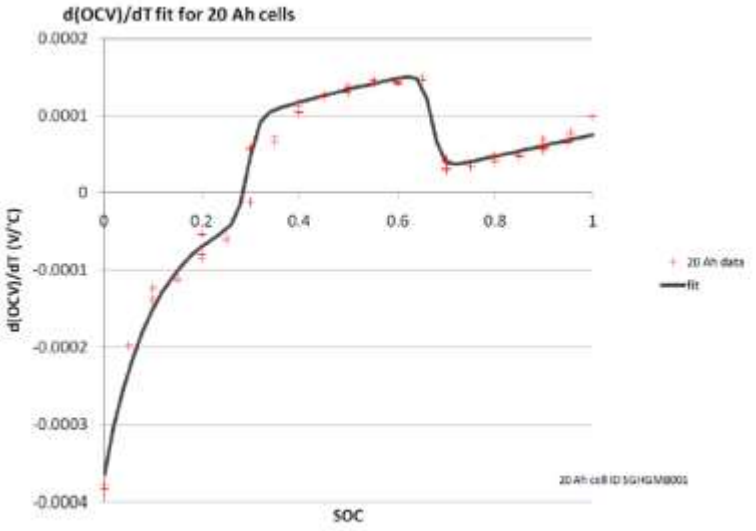
$$q_{gen} = \underbrace{I^2 \cdot R_{total}}_{\text{irreversible Heat (joule heat)}} + \underbrace{I \cdot T \cdot \frac{dU}{dT}}_{\text{reversible heat (entropic heat)}} \quad [W]$$

entropic coefficient

Context and Calculation

- Entropic coefficient

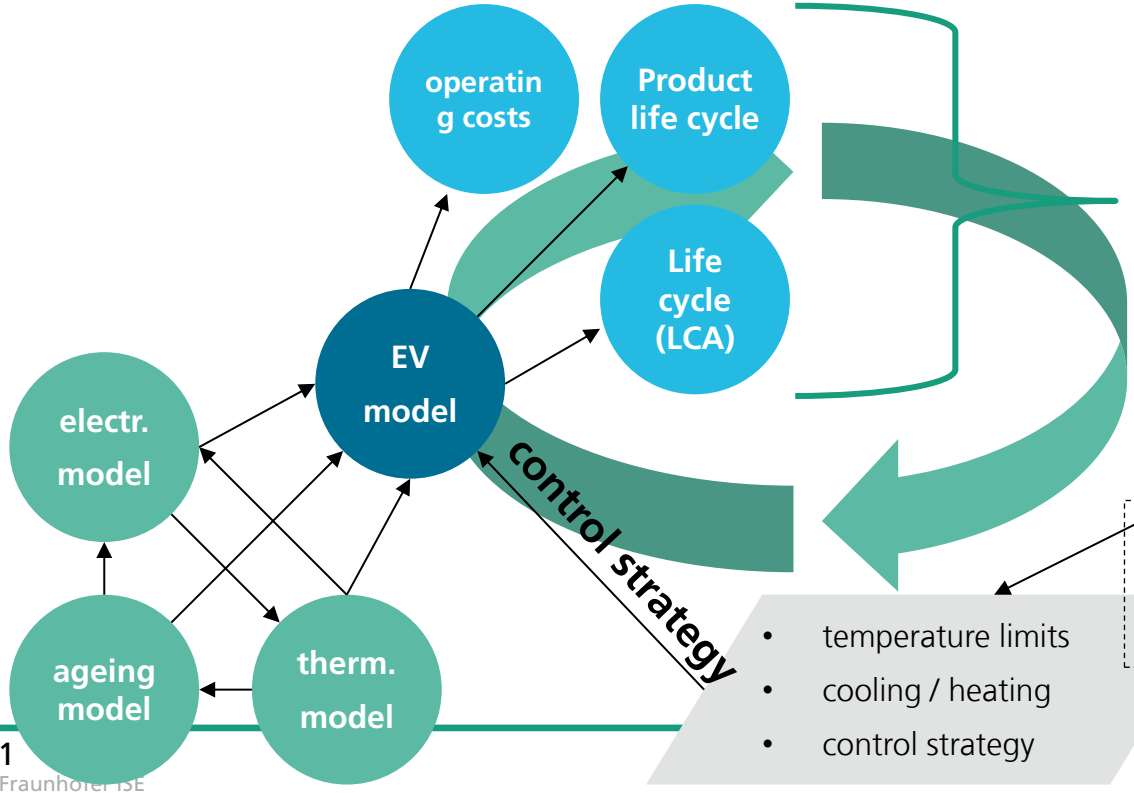




right graph: [Battery Pack Design, Validation, and Assembly Guide using A123 Systems AMP20M1HD-A Nanophosphate Cell – 07.02.2014 – A123 Systems - Online]

Thermal Management Strategy

- Determination of parameters

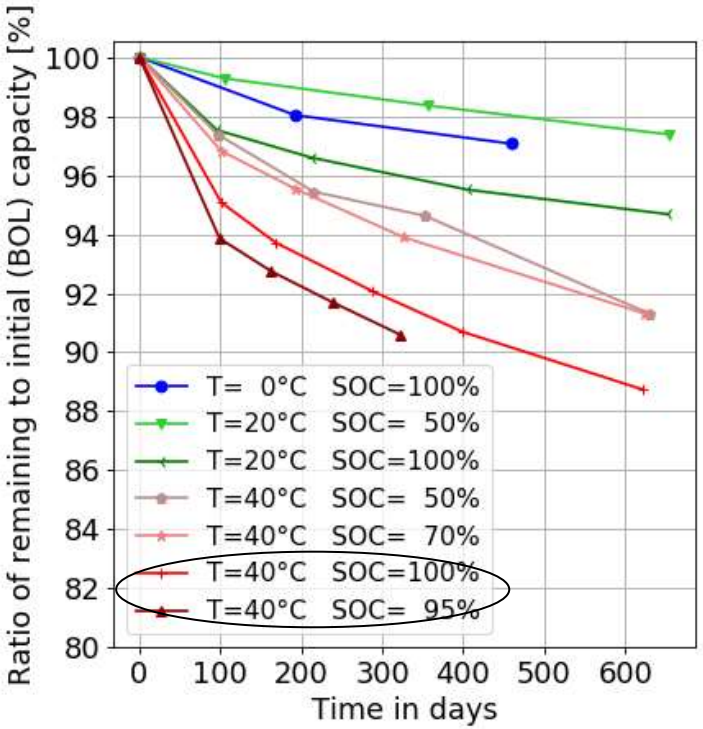


Example of control strategy:

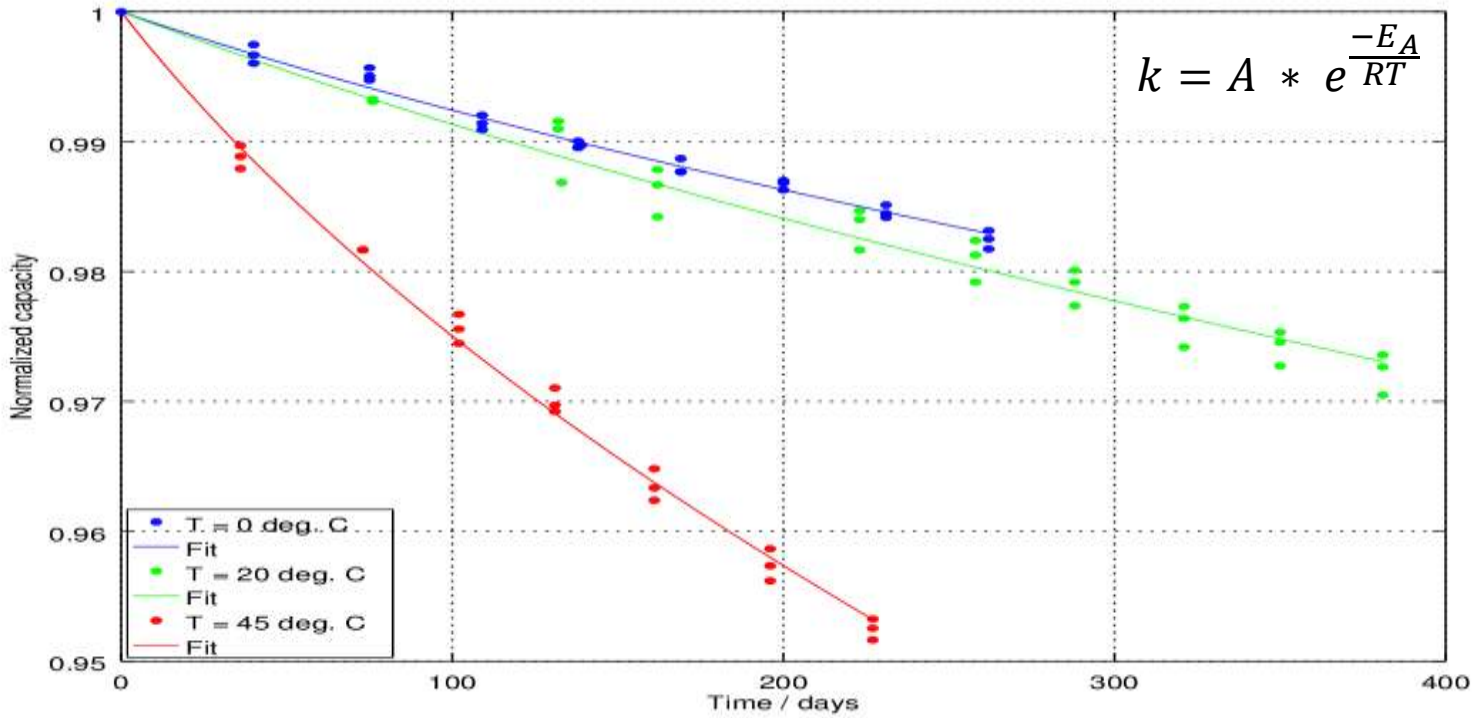
Cooling to 20°C when grid connected

→ less calendric ageing

Background – calendric ageing



Background – calendric ageing, Sony US18650V3



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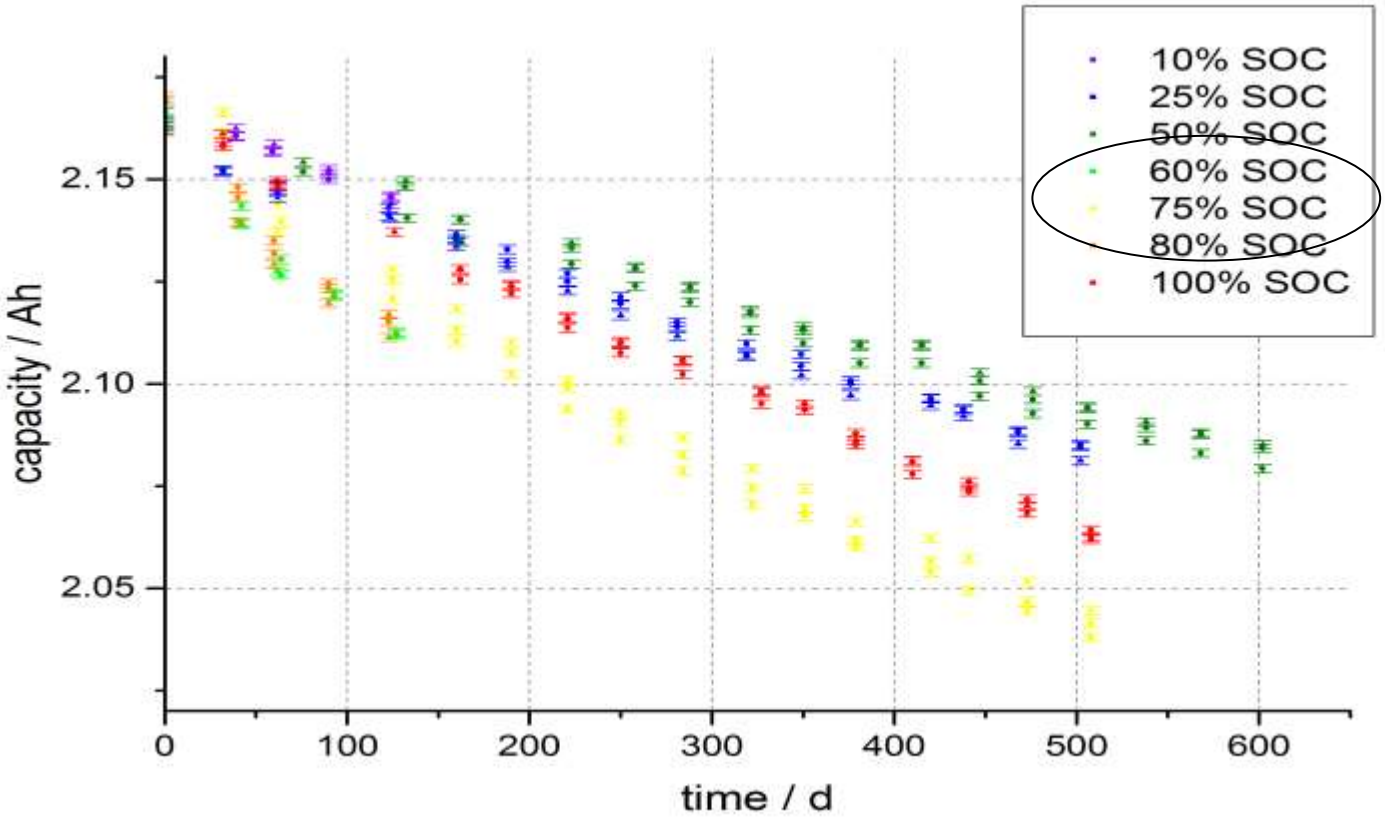
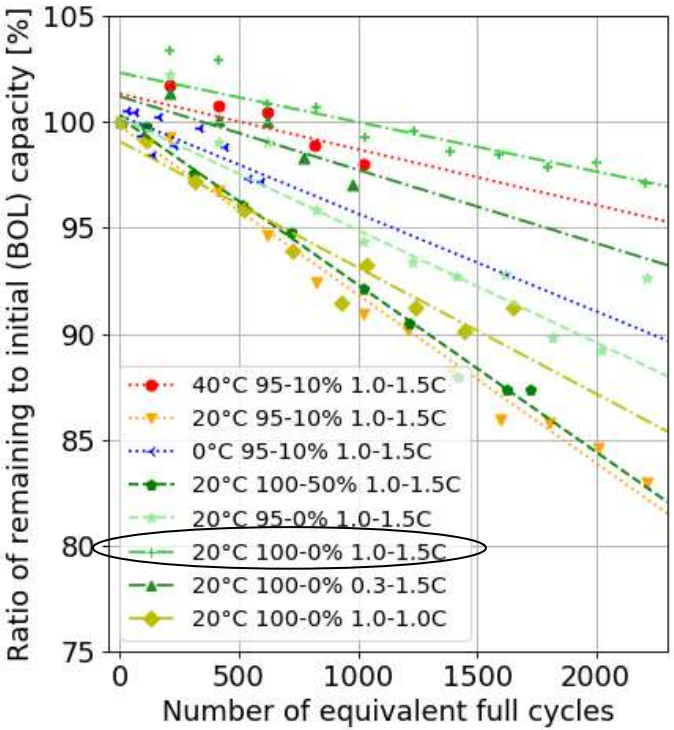
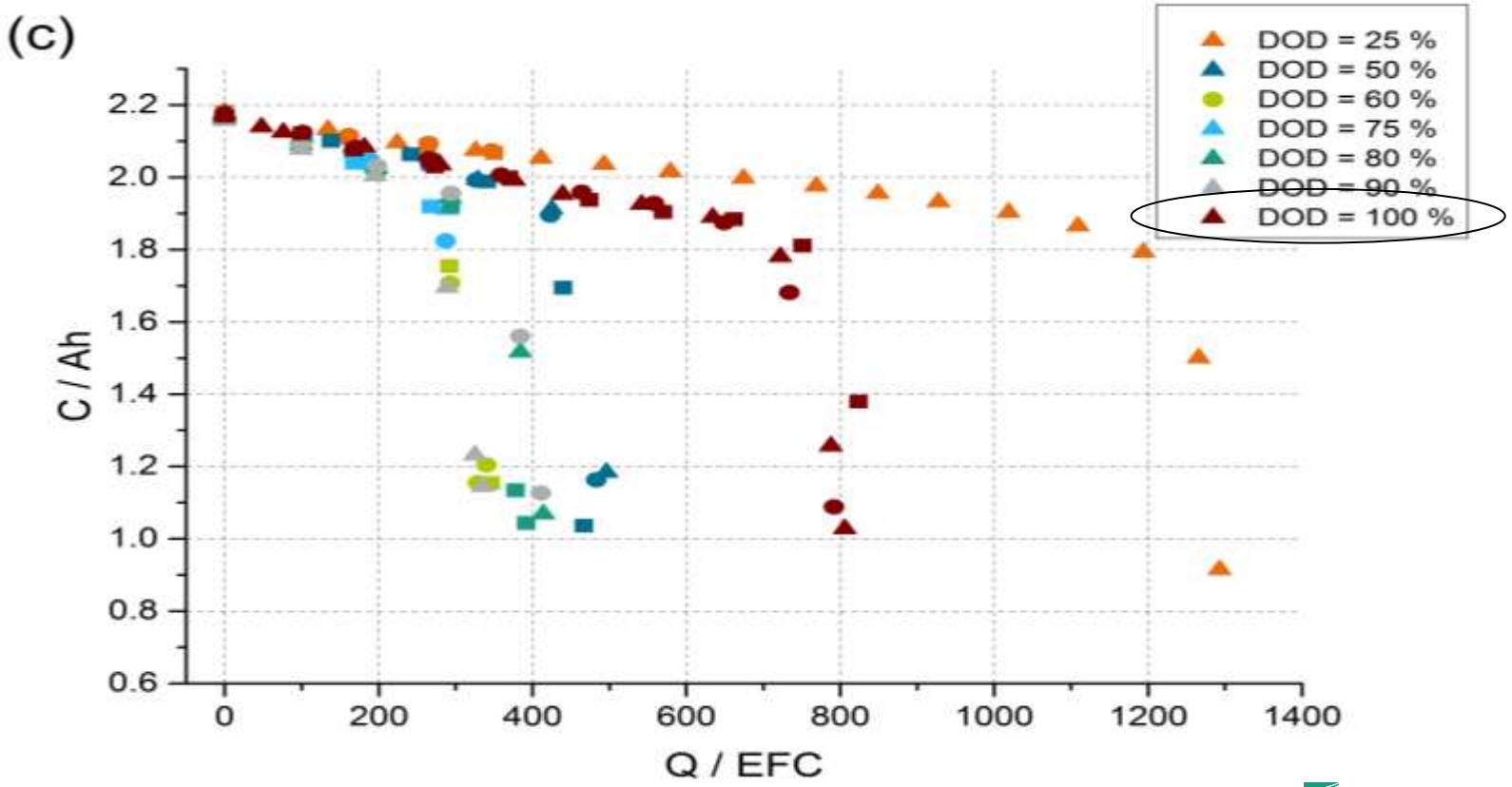
Background – calendric ageing, Sony US18650V3



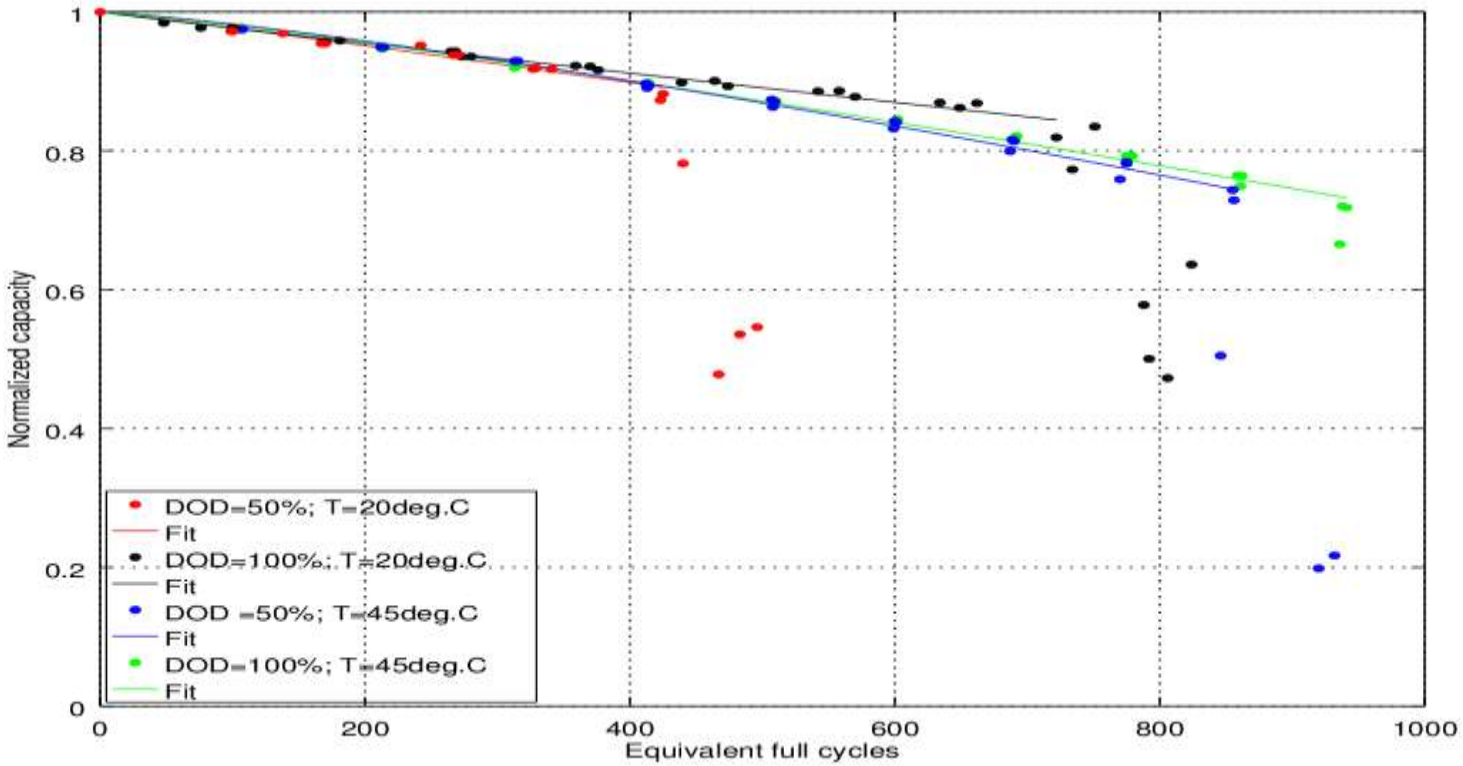
Background – cyclic ageing



Background – cyclic ageing, Sony US18650V3 @ RT

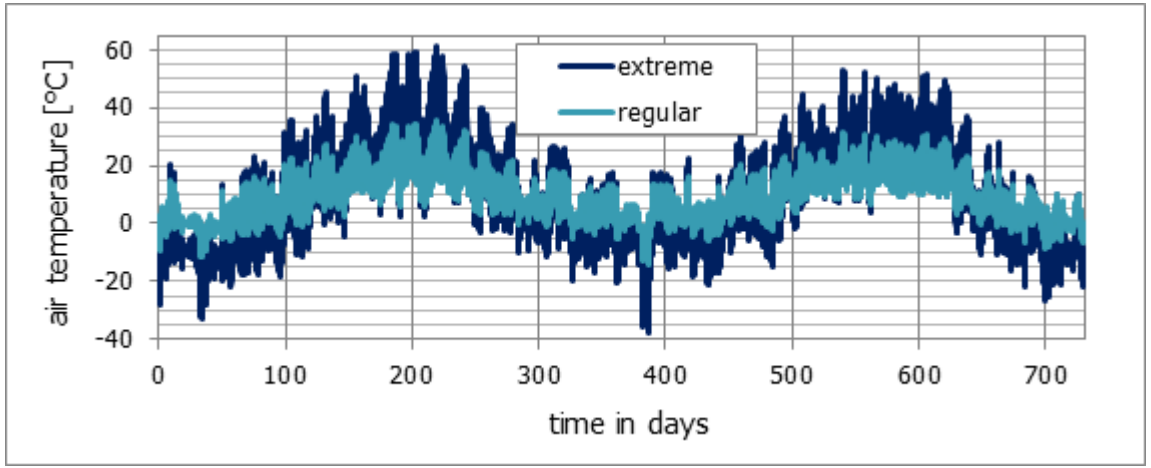


Cyclic Ageing – DOD and high Temperature



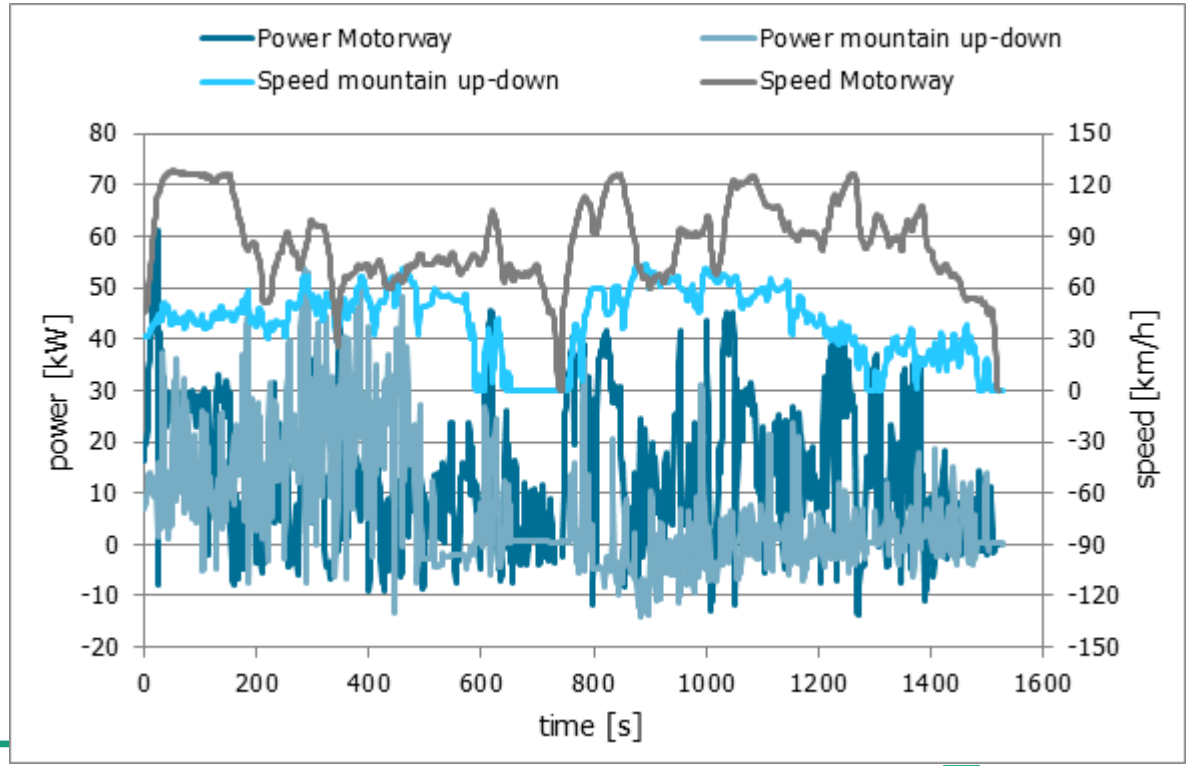
Thermal Management - Battery

- Environmental temperatures
  - air temperature in Augsburg 1h
    Source: Deutschen Wetterdienst 2015-2017



Thermal Management - Battery

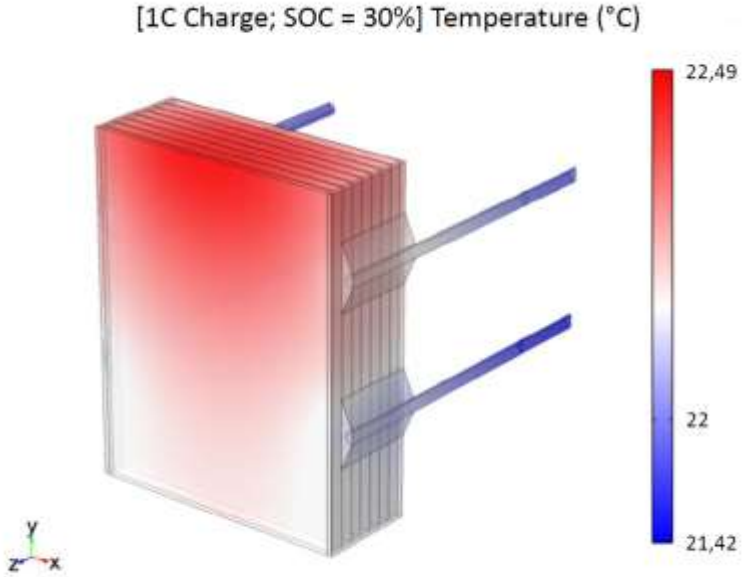
- Load profile
  - Measured with Stromos
    (German E-Cars GmbH)



Significance for applications

Goal: less battery ageing + higher system efficiency

- Thermal Management
  - Accurate sizing of heating & cooling systems
  - (Pre-) conditioning of battery operating temperature
  - Strategy: warm operation / cold standby (possibly even cooling)
  - Prediction of climatisation need



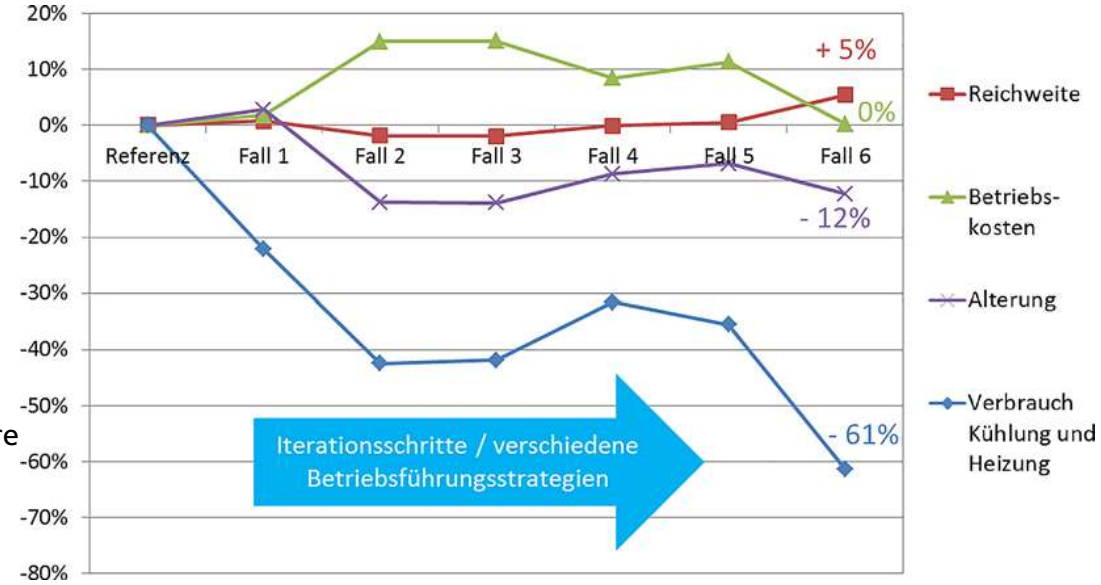
Thermal Management strategy
Project JOSPEL

- Control strategy components:
  - Battery Preconditioning
  - Standby cooling
  - Various temperature boundaries (soft & and hard boundaries)
  - …

- To be optimized
  - Energy use while driving in kWh
  - Relative energy use kWh / 100km
  - Operating costs € / 100 km
  - Ageing SOH (State of Health)
  - Lifetime [years]
  - Lifetime [km total]

Thermal Management strategies

- Exemplary effects of thermal Management
  - Various strategies and operation parameters
- Results
  - Scenario 6:
    - Less energy consumption
    - Less battery ageing
    - Less energy use while driving → more range



Thank you for your attention!

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