THIRD EDITION

# extended

NEXT GENERATION OF MULTIFUNCTIONAL, MODULAR AND SCALABLE SOLID STATE BATTERIES SYSTEM

## Newsletter - June 2025


## ABOUT THE PROJECT

**EXTENDED**, a Horizon Europe project, is a collaborative effort bringing together 19 partners from 10 EU countries! Our mission is to design, develop, and validate the next-generation battery pack systems that will drive the mass-market adoption of electric vehicles and applications.


***Igniting Battery Advancements, Powering a Sustainable Future.***

## NEWSLETTER CONTENT

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# MILESTONE MOMENTS


## 3º GENERAL ASSEMBLY MEETING

JULY 2024

The third General Assembly of the **EXTENDED** project gathered 19 partners from 10 EU countries. Held on 2-3 July at the Grande Hotel do Porto, it was kindly hosted by **INEGI**.

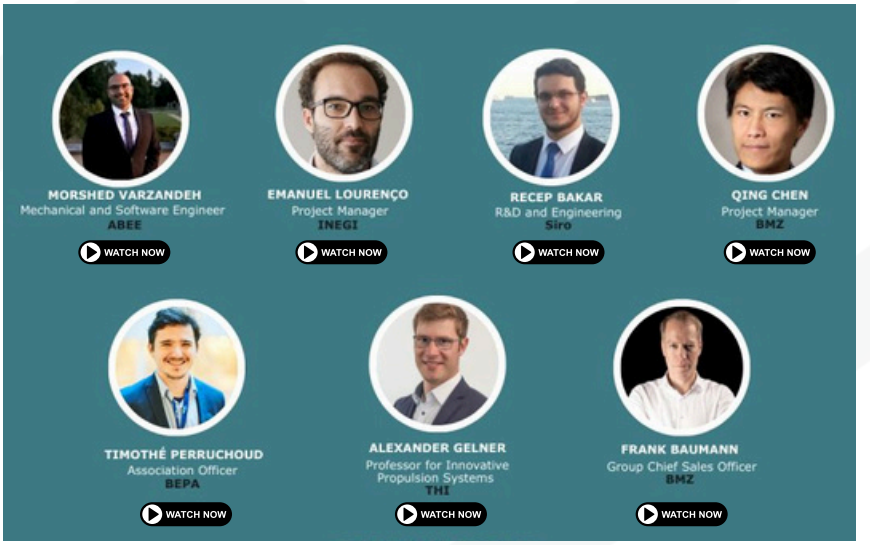
Partners came together to discuss progress and define the next steps. The event featured integration moments that strengthened collaboration. This assembly marked an important milestone in the project. Valuable insights were exchanged, and future phases were planned. It fostered innovation and reinforced the project's shared goals.

Participants left motivated to advance the project further.

## WEBINAR: "DECODING THE CLIMATE IMPACT OF MODULAR BATTERY SYSTEMS"

JULY 2024

We hosted our first online webinar, **"Decoding the Climate Impact of Modular Battery Systems"**. Live-streamed, the session featured seven project members sharing insights on the environmental impact of propulsion systems and the potential of modular battery solutions.




Special thanks to **Morshed Varzandeh (ABEE)**, **Emanuel Lourenço (INEGI)**, **Dr. Recep Bakar (Siro Energy)**, **Qing Chen (BMZ Germany)**, **Timothé Perruchoud (BEPA)**, **Alexander Gelner (TH Ingolstadt)**, and **Frank Baumann (BMZ)** for their valuable contributions.

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# MILESTONE MOMENTS


## ANNUAL COLLABORATION MEETING

OCTOBER 2024

**EXTENDED** participated in the annual collaboration meeting with the **Joint Research Centre**, **BEPA**, and the **2Zero Partnership**, held in Petten, Netherlands. Our project coordinator, **Bruno Rodrigues**, proudly represented us at the event.

The meeting was a valuable platform to exchange insights on next-generation battery technologies and discuss industry-aligned policies for future energy and mobility systems. In addition, the EXTENDED Project Coordinator Bruno Rodrigues (ABEE) also shared EXTENDED's latest progress alongside fellow EU projects like **BATSS**, **NEXTBAT**, **TEMPEST**, and **VERSAPRINT**.

## BATTERY EXPERTS FORUM 2024

NOVEMBER 2024

The **EXTENDED** team participated in the Battery Experts Forum 2024, Europe's largest battery conference, held from 5–7 November in Darmstadt, Germany.

As an exhibitor, **BMZ Germany GmbH** showcased its innovative battery solutions and modular platforms. **CEO Sven Bauer** shared insights on global battery market challenges and opportunities in his speech, **"World Market"**.

**Dr. Recep Bakar** from **Siro Energy** presented on **"Innovative Recycling of Critical Materials"**, emphasizing sustainable practices in lithium-ion battery recycling.

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# MILESTONE MOMENTS

## GENERAL ASSEMBLY AND 1ST REVIEW MEETING OF EXTENDED

FEBRUARY 2025


The **General Assembly and First Review Meeting** of **EXTENDED** took place from February 5 to 6 at the **ABEE facilities** in Ninove, Belgium.

This milestone event brought together our consortium to assess progress and align strategies. The **review meeting** provided an opportunity to showcase **our achievements** and **discuss the next steps** towards our shared objectives.

**A big thank you to ABEE for hosting us!**

## EXTENDED REVIEW MEETING KICKS OFF WITH A LIVE DEMO

NOVEMBER 2024

The first day of the project meeting began with a DEMO session showcasing our key achievements, followed by a presentation of the progress the consortium has made so far.

The live demo brought some of the solutions to life by demonstrating their capabilities in real time.

It was a great opportunity to see our work in action and set the stage for insightful discussions ahead.

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# MILESTONE MOMENTS


## 8TH EDITION OF RTR CONFERENCE

FEBRUARY 2025

The 8th edition of the **RTR Conference** was held in Brussels in February 2025. During the 3 days of event were expected more than **400 participants** to interact in **26 sessions**, more than **90 projects** and **100 speakers**. Participants learned about Horizon 2020 and Horizon Europe projects' results, expected impacts, and what the next research steps are in essential areas for road transport: Green Vehicles, Urban Mobility, Logistics, Intelligent Transport Systems, Safety, Automated Road Transport.

As part of **Session 6**, during the day 1, we had the opportunity to showcase **EXTENDED**. **Maximilian Mellin** from **BMZ Germany GmbH**, presented **our latest advancements in high-performance and safe-by-design next-generation battery systems**. **TEMPEST**, **VERSAPRINT EU**, **NEXTBAT**, and **BATSS EU** projects also participated of this inspiring discussion moderated by **Martha Gialampouki (CINEA)** and **Manasa Sridhar (IVECO Group)**.

**WATCH NOW**

## 32ND CIRP CONFERENCE ON LIFE CYCLE ENGINEERING (LCE2025)

NOVEMBER 2024

**EXTENDED** have participated in the 32nd CIRP Conference on Life Cycle Engineering (LCE2025) between 7th to 9th April 2025 at The University of Manchester, United Kingdom (UK). Representing **INEGI** and the **EXTENDED**, our team contributed to the conversation on advancing sustainable and circular manufacturing.


**Rafaela Gonçalves's** presentation, **"Sustainable Battery Design: Lean Design for Excellence as an Enabler"** highlighted insights on how Lean Design for Excellence (DfX) can drive the development of more sustainable and circular battery systems, a crucial enabler of the green and digital transition in both mobility and energy sectors.

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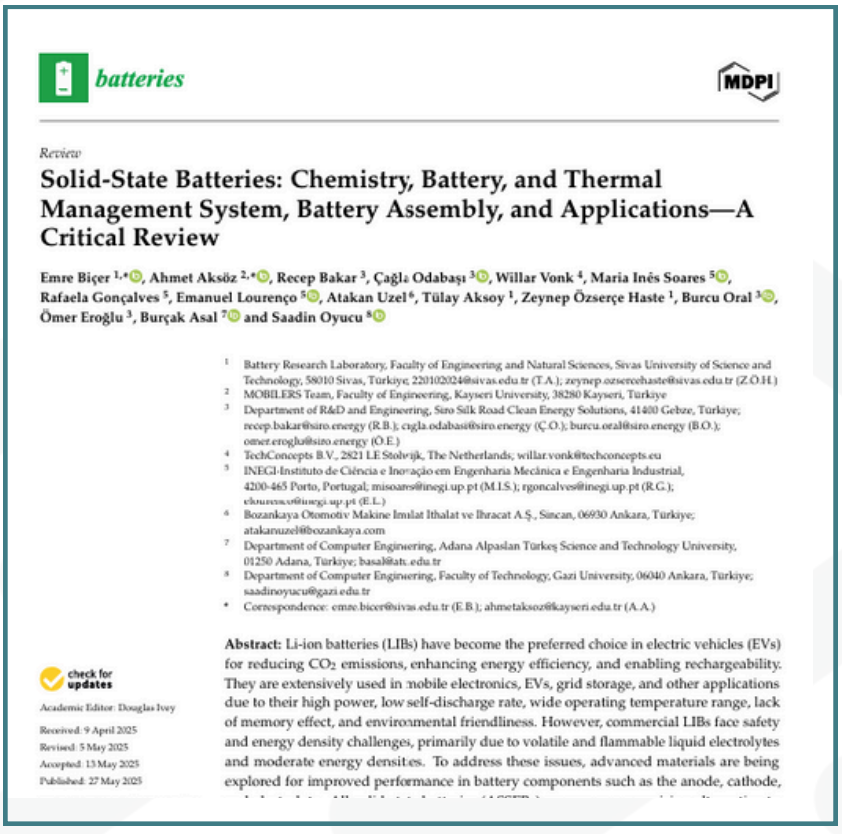
# RECENT ACHIEVEMENTS

## NEW PUBLICATION

We are excited to announce the publication of our review article, **"Solid-State Batteries: Chemistry, Battery, and Thermal Management System, Battery Assembly, and Applications—A Critical Review,"** featured in the journal **Batteries** as part of the Special Issue Electrolytes for Solid State Batteries—2nd Edition. These publications highlight EXTENDED's dedication to advancing battery technology and sharing impactful research with the community. Stay connected for upcoming updates and innovations from our passionate research team.



batteries

MDPI

Review

**Solid-State Batteries: Chemistry, Battery, and Thermal Management System, Battery Assembly, and Applications—A Critical Review**

Emre Biçer [1,*], Ahmet Aksöz [2,*], Recep Bakar [3], Çağla Odabaşı [3], Willar Vonk [4], Maria Inés Soares [5], Rafaela Gonçalves [5], Emanuel Lourenço [5], Atakan Uzel [6], Tülay Aksoy [1], Zeynep Özserçe Haste [1], Burcu Oral [3], Ömer Eroğlu [3], Burçak Asal [7] and Saadin Oyucu [8]

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**Abstract:** Li-ion batteries (LIBs) have become the preferred choice in electric vehicles (EVs) for reducing $CO_2$ emissions, enhancing energy efficiency, and enabling rechargeability. They are extensively used in mobile electronics, EVs, grid storage, and other applications due to their high power, low self-discharge rate, wide operating temperature range, lack of memory effect, and environmental friendliness. However, commercial LIBs face safety and energy density challenges, primarily due to volatile and flammable liquid electrolytes and moderate energy densities. To address these issues, advanced materials are being explored for improved performance in battery components such as the anode, cathode,

Published in the journal **Batteries**, this article led by the partner **AKSOZ TECHNOLOGY** explores innovative modeling techniques and system design strategies for Li-ion batteries, focusing on enhancing battery management through multi-domain digital approaches. It contributes to advancing the reliability and efficiency of battery systems in practical applications.
Reed the full artice.

CLICK HERE

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# RECENT ACHIEVEMENTS

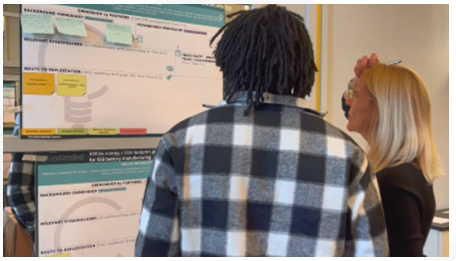
## SUCCESSFUL SECOND EXPLOITATION WORKSHOP TO IDENTIFY IP

**EXTENDED** is set to revolutionize the battery ecosystem through generating innovative technologies and knowledge. To ensure that our achievements reach their full potential, we will create an exploitation plan for each 'Key Exploitable Result' (KER).

In our last newsletter, we highlighted the first Exploitation workshop, which was held in December 2023 to identify the KERs. As a next step, **TechConcepts** organized a second interactive consortium workshop to identify the relevant background and foreground IP assets associated with each KER, along with their respective owners.

The workshop was combined with a teambuilding activity organized by **TechConcepts**, in which the consortium members had to form mixed teams to successfully cross the artificial river Douro.

The interactive teambuilding and exploitation sessions not only led to a great collection of new insights, but also fostered team bonding.



Future General Assembly meetings will feature more workshops by **TechConcepts** to further detail the KERs and develop comprehensive exploitation plans. These efforts aim to engage all partners in driving the project's results to new heights.

Check out **TechConcepts'** video of the Porto meeting and workshop.
Congratulations to all partners for their dedication and teamwork!

**WATCH NOW**

# RECENT ACHIEVEMENTS

## ELECTRICAL CHARACTERIZATION OF CELLS

To ensure accurate characterization of the cells, a specialized setup was designed and assembled. Given the sensitivity of solid-state batteries to pressure, the setup incorporates two steel plates that sandwich the battery cell, with threaded rods and compression springs regulating the applied force. Two resistive force sensors were installed to monitor and confirm the pressure applied to the cells throughout the tests. This arrangement guarantees consistent contact resistance at the interfaces, a critical factor for reliable performance. The setup (Figure 1) was placed inside a climatic chamber to enable controlled testing across various temperatures (15°C, 25°C, and 45°C), ensuring that environmental factors were well accounted for during the experiments.

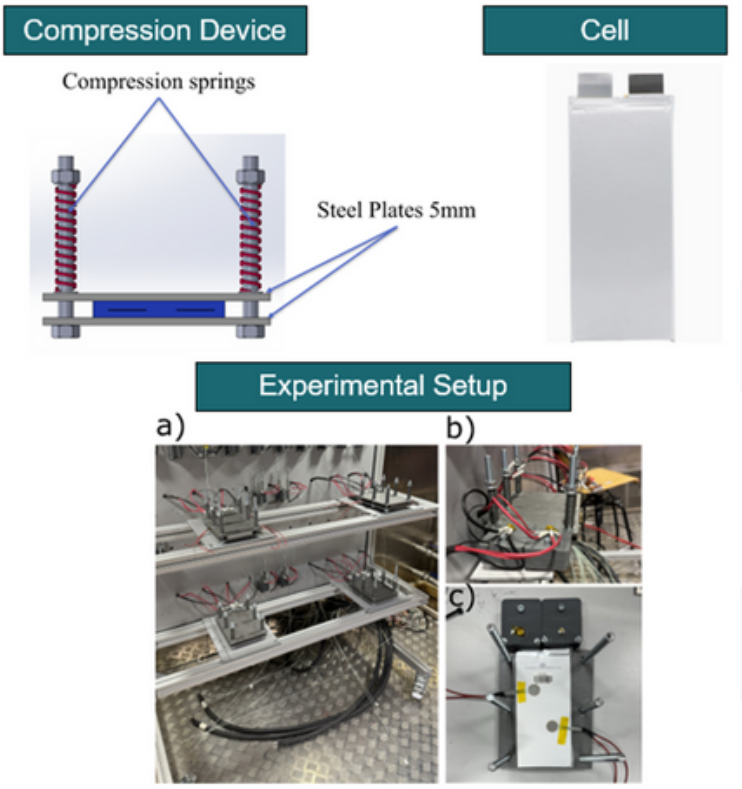



*Figure 1: Images of the experimental setup designed for the semi-solid cell electrical characterization: Cell's final lay-out in the climatic chamber (a), cell pressure set up closer view (b) and installation of force sensors over the cell*

The cells underwent a comprehensive series of tests to evaluate their performance under various conditions.

These tests included preconditioning, capacity assessments, Hybrid Pulse Power Characterization (HPPC), and discharge test at multiple C-rates and temperatures, as outlined in the schematic flowchart (Figure 2). Preconditioning ensured that the cells achieved stable discharge capacity within ±3% of the nominal value. Additionally, HPPC tests were performed to extract key parameters such as open-circuit voltage (OCV), internal resistance, and polarization resistance as functions of state-of-charge (SoC) and temperature. These parameters were instrumental in developing an equivalent circuit model (ECM).

Based on the experimental data (Figure 3a and 3b), an equivalent circuit model was developed. The ECM, employing a second-order approach (Figure 2), accurately replicates the voltage response of the cells under different loads and temperatures.

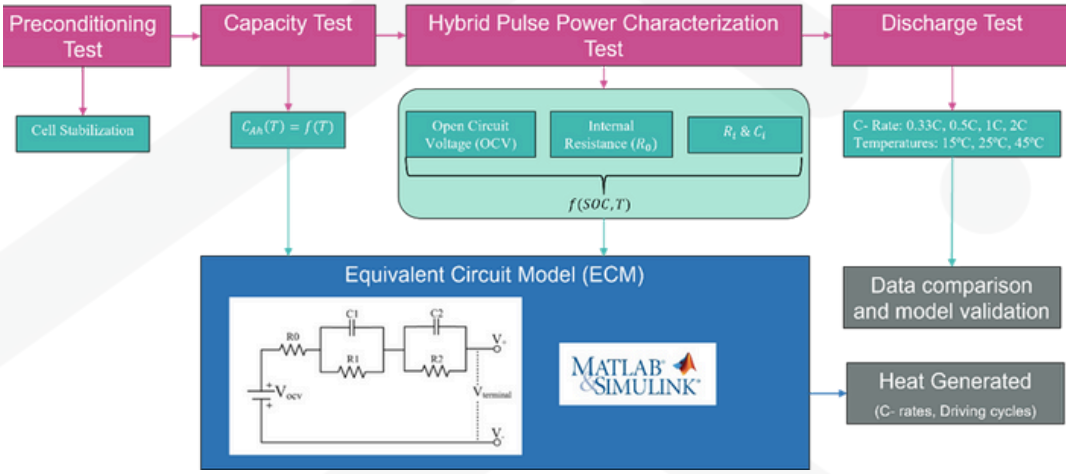



*Figure 2: flowchart of the characterization process and the development of the equivalent circuit model (ECM) with MATLAB-Simulink.*

The primary application of the ECM model in this project is to calculate the heat generated by the cell during its operation. By defining a representative load profile, using information supplied by project partners, the model can simulate the heat generation under real-world conditions. This capability allows for the evaluation of thermal behavior in various usage scenarios. The model also supports the development of cooling strategies and thermal control mechanisms tailored to specific operational conditions.

Two representative plots are shown below (Figure 3): one illustrating a typical load profile and another displaying the corresponding heat generated over time. This approach demonstrates the practical utility of the model in predicting thermal performance and ensuring safe and reliable operation.

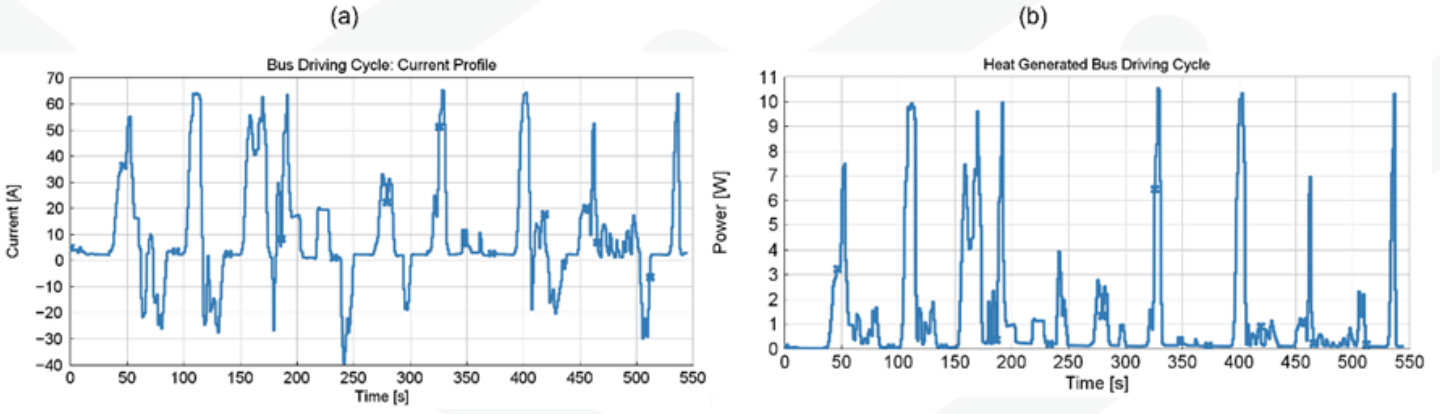
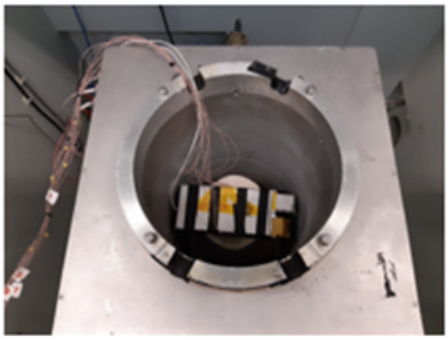



*Figure 3: Current profile and corresponding heat generation for a bus driving cycle. (a) current profile applied to the battery, (b) the heat generated during the same cycle*

## THERMAL CHARACTERIZATION OF CELLS

The aim of this characterization is to obtain the specific heat capacity (Cp) and the heat conductivity of the cell. These values are key to evaluate the heat transfer through them, to properly design the thermal management system. For this purpose, different experimental set up have been used, involving an accelerated rate calorimeter and a hot disk device (Figure 3). The data extracted from these tests will be used in the different models to properly simulate the thermal behavior of the cells.

(a)



(b)

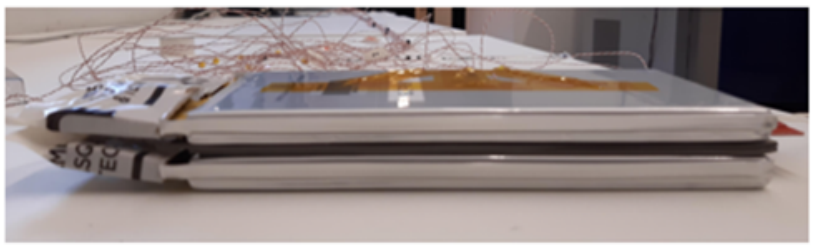


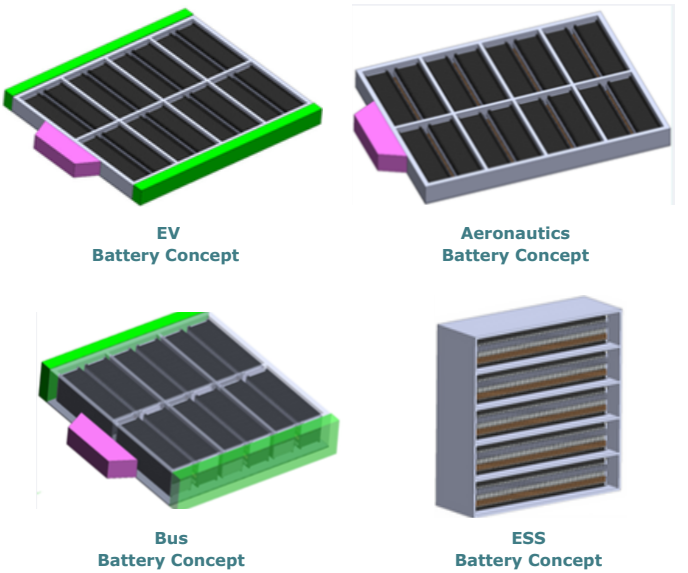
*Figure 4: (a) Calorimeter configuration; (b) Hot disk configuration*

THIRD EDITION

# RECENT ACHIEVEMENTS

## BATTERY DESIGN CONCEPTS

We updated our battery design concepts for 4 different use cases: EV, E-Bus, Stationary & Aeronautics according to the new semi-SSB cell. Based on the dimensions, proposed light-weight materials and the performance of the cell, the performance values for the different use cases e.g. gravimetric and volumetric pack power and energy density are compared to the KPI's, general requirements and baseline values, showing enhanced performance of our concept designs.



EV Battery Concept

Aeronautics Battery Concept

Bus Battery Concept

ESS Battery Concept

## LIGHTWEIGHT ENCLOSURE

For Task 5 lightweight materials namely the polymer composite PC/ABS was selected for 3D printing of the demonstrator enclosure and the cell holders. This material is highly flame retardant and its toughness will be enhanced by carbon or glass fiber fillers. Additional coatings, e.g. intumescent materials will be tested to further increase the flame-retardant properties of the housing. Due to the lesser pre-pressure requirements for the semi-SSB cell, further weight reduction can be applied on the housing and cell holders. Additionally, graphite heat spreaders and housing sealings will be used to further decrease the weight. To ensure coherence of the design and enhanced function integration and dismantling, information based on thermal and electrical solutions and manufacturing will be included in the next demonstrator design proposal by BMZ.

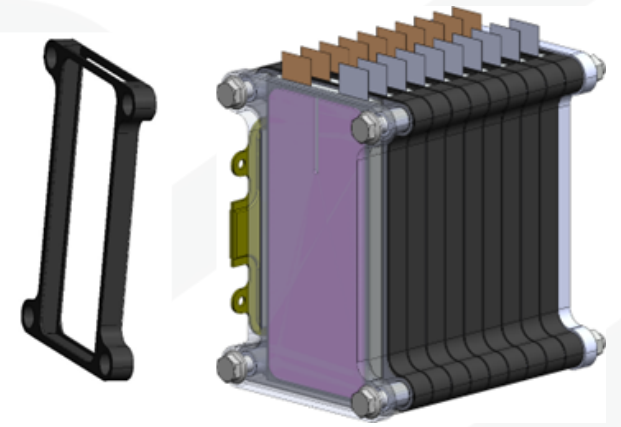


Figure 5: Cell holder concept made of filler-enhanced polymer composite, BMZ concept with a cooling plate and heat spreaders between the cells.

## INNOVATIVE APPROACHES IN BATTERY MANAGEMENT SYSTEM (BMS) DEVELOPMENT

Fraunhofer IISB

In the recent project months of **EXTENDED**, the development of novel Battery Management System (BMS) solutions has achieved significant progress. The focus of WP3 is on the development of wireless communication strategies and innovative, single cell based BMS solutions, and impedance-based state estimators. In Table 1, the developed solutions are presented:

*Table 1 Description of the EXTENDED BMS-solutions*

| Sensor Type | Responsible Partner | Key innovation |
|---|---|---|
| Single cell EIS sensor | FHG IISB | 1. Impedance based cell core temperature and pressure estimation<br>2. Contactless communication<br>3. Single cell approach |
| Single cell printed sensor | LUM | 1. Multi point temperature and pressure sensing<br>2. New RF based communication protocol design based on IEEE 802.15.4 MAC Layer<br>3. Single cell approach |
| Optical cell to cell daisy chai | LUM | 1. Triggering of synchronous voltage and current measurements<br>2. Optical daisy chain communication<br>3. Single cell approach |

Figure 1 shows the single cell EIS sensor, developed by Fraunhofer IISB.

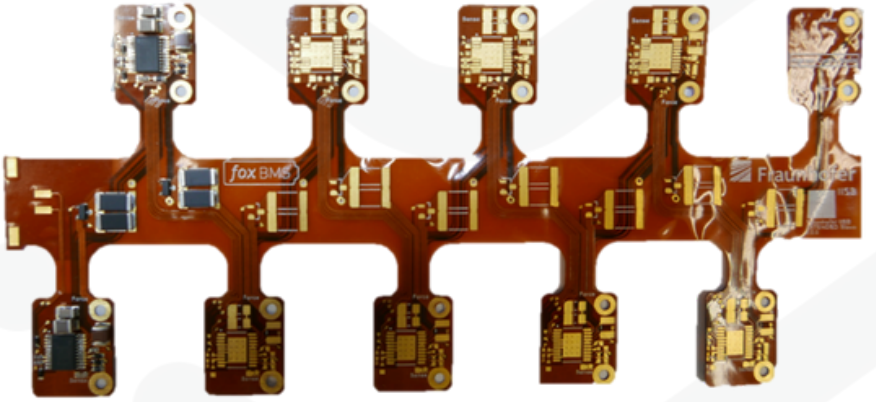



*Figure 6: Flexible PCB with single cell EIS sensors (FHG IISB*

# RECENT ACHIEVEMENTS



As a control and management unit, the open source BMS platform foxBMS is used to provide a proven BMS-Master solution. To assure the foxBMS BMS-Master compatibility with the developed BMS-Slave solutions, wireless communication gateways (optical and RF-based) are designed in the scope of WP3.

A first version of the EIS sensor was successfully validated with the foxBMS BMS-Master, being able to acquire the relevant cell parameters such as cell voltage, -impedance and -temperature from the EXTENDED SSSB cell. The first impedance measurement results are presented in Figure 2.

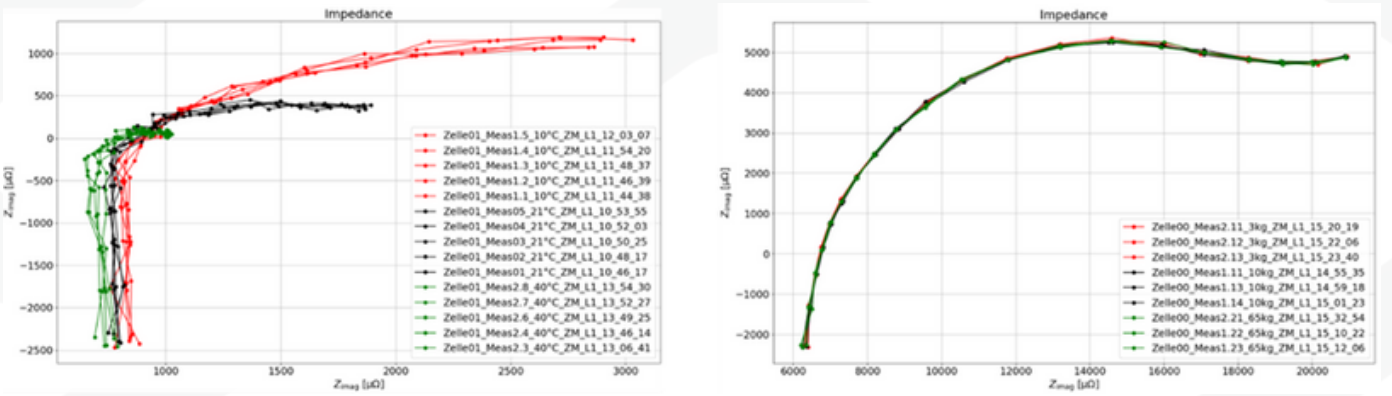



*Figure 7: Nyquist plots of the acquired cell impedance with the developed EIS sensing electronics at different battery cells and cell temperatures*

In a next step, the developed BMS-Slaves will undergo further test and validation procedures to optimize the design for maximum performance and integrability into the battery module. Moreover, extensive cell testing activities will be performed to develop cell impedance-based core temperature and pressure related state estimators.

THIRD EDITION

# VOICES OF IMPACT

In this edition, **Fraunhofer** partner selected the key figure to be interviewed. We are proud to feature **Doniyor Urishov- Research scientist at VTT and PhD student at Aalto University**

**1. How can accurate state estimator algorithms improve the performance, lifespan, and safety of solid-state battery systems?**

Accurate state estimator algorithms (for charge, health, and temperature) help solid-state batteries perform better, last longer, and operate more safely by preventing overcharging, overheating, and unexpected failures. This is especially important for EVs, ships, and heavy-duty vehicles where reliability and safety are critical.

**Doniyor Urishov**
Research scientist at VTT and PhD student at Aalto University

**2. Wireless communication strategies ease the transfer of battery data during operation, including Cloud solutions. What are benefits of Cloud solutions and how can they impact future battery system operation?**

SCloud-based battery systems enable real-time monitoring, predictive maintenance, and real-time updates, improving battery management and reducing downtime. They also allow centralized data analysis, helping optimize battery performance across multiple vehicles or vessels.

**3. Is there an approach to reduce physical cell testing during SSB system development?**

Digital twins, simulations, and AI models reduce the need for physical cell testing by predicting battery behavior virtually. These tools speed up development and lower costs while ensuring safer, more efficient solid-state battery designs.

**Doniyor Urishov research focuses on modeling Li-ion batteries and developing battery management systems using multi-domain digital twins. Since 2019, he has been leading technical coordination for the EU-funded BATMAX project, driving innovation in battery technology.**

THIRD EDITION

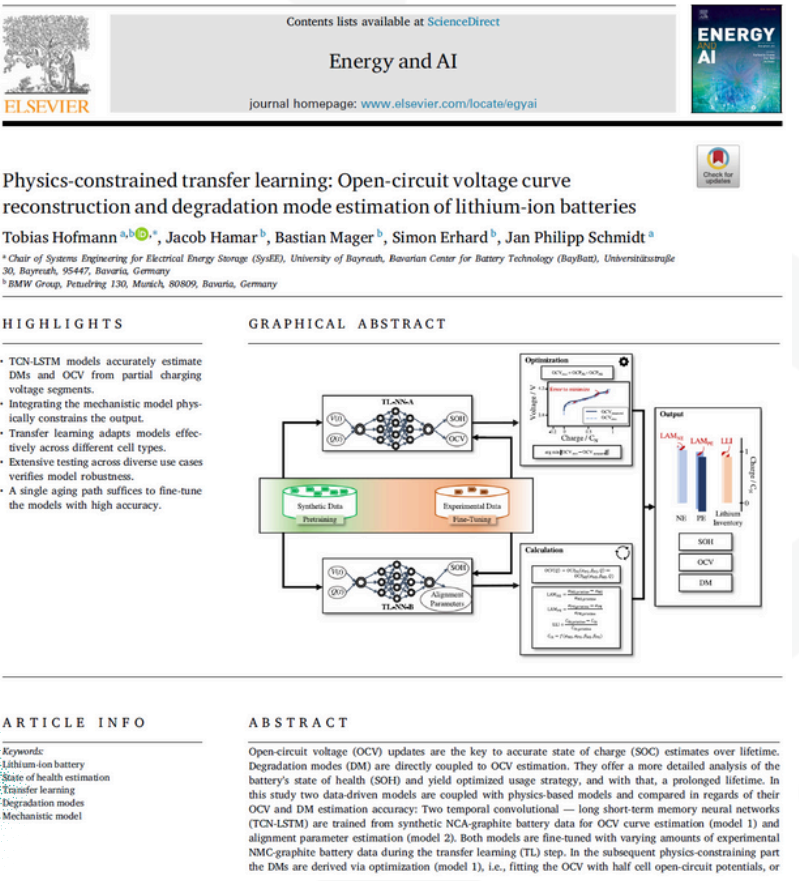
# NAVIGATING EXCELLENCE

## Top Picks from EXTENDED partners

In the third edition of the **EXTENDED** newsletter, we take great pride in presenting **Matthias Hessmann,** Fraunhofer IISB's top pick.

Fraunhofer IISB

**Matthias Hessmann** graduated as a mechatronic engineer (M.Sc.) in 2023 from Friedrich-Alexander-University (FAU) Erlangen-Nuremberg. In early 2024, he joined the Group Battery Systems at Fraunhofer IISB as a full-time scientific employee. During this period, he was involved in different publicly funded projects (both domestic and EU), contributing to mechanical, electrical, and electronics development at battery system and component level.



Contents lists available at ScienceDirect

Energy and AI

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Physics-constrained transfer learning: Open-circuit voltage curve reconstruction and degradation mode estimation of lithium-ion batteries

Tobias Hofmann [a,b], Jacob Hamar [b], Bastian Mager [b], Simon Erhard [b], Jan Philipp Schmidt [a]

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HIGHLIGHTS

- TCN-LSTM models accurately estimate DMs and OCV from partial charging voltage segments.
- Integrating the mechanistic model physically constrains the output.
- Transfer learning adapts models effectively across different cell types.
- Extensive testing across diverse use cases verifies model robustness.
- A single aging path suffices to fine-tune the models with high accuracy.

GRAPHICAL ABSTRACT

ARTICLE INFO

*Keywords:*
Lithium-ion battery
State of health estimation
Transfer learning
Degradation modes
Mechanistic model

ABSTRACT

Open-circuit voltage (OCV) updates are the key to accurate state of charge (SOC) estimates over lifetime. Degradation modes (DM) are directly coupled to OCV estimation. They offer a more detailed analysis of the battery's state of health (SOH) and yield optimized usage strategy, and with that, a prolonged lifetime. In this study two data-driven models are coupled with physics-based models and compared in regards of their OCV and DM estimation accuracy: Two temporal convolutional — long short-term memory neural networks (TCN-LSTM) are trained from synthetic NCA-graphite battery data for OCV curve estimation (model 1) and alignment parameter estimation (model 2). Both models are fine-tuned with varying amounts of experimental NMC-graphite battery data during the transfer learning (TL) step. In the subsequent physics-constraining part the DMs are derived via optimization (model 1), i.e., fitting the OCV with half cell open-circuit potentials, or

"I have chosen this paper due to the desire to continuously enhance existing battery technology in order to maximize battery efficiency. A deep understanding of battery behaviour is crucial for accurate predictions of State of Charge (SOC) and State of Health (SOH). The approach of this paper, combining data-driven and physics-based based models before optimization with experimental data not only reduces the need for extensive battery cell testing but also facilitates the prediction of cell aging behavior based on historical data. This paper thus addresses key advancements in state-of-the-art battery technology and presents innovative solutions for improved OCV and degradation mode estimations. The described innovative approach of improving predictive models can not only support the development of advanced battery cell and battery system but also helps to optimize the operational efficiency of battery systems."

Matthias Hessmann

The **EXTENDED** newsletter is released semi-annually with the primary goal of fostering awareness about our project and its results, shedding light on the transformative impact of battery development on eco-friendly transportation.

# DIVE INTO OUR WORLD!

Stay informed about our project and the dynamic field of battery development.

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**SUBSCRIBE**

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