Battery Cell Production Germany

The funded projects of the Federal Ministry for Economic Affairs and Energy (BMWE) support programs for battery cell production

To ensure competitiveness, employment in the automotive and energy sectors, and the successful establishment of a sustainable battery industry in Germany, innovations at all levels of the value chain, in every detail, and across all implementation dimensions are essential. For this purpose, the Federal Ministry for Economic Affairs and Energy (BMWE) launched the “Battery Cell Production Germany” initiative in November 2018, consolidating its battery-related activities in Germany. The BMWE’s goal is not only to promote industrial projects but also to network the research, training, and corporate landscape.

Under the umbrella of the Battery IPCEIs, the BMWE supports industrial projects with investments in battery research and production. IPCEI funding is a European initiative that makes a significant contribution to growth, employment, and competitiveness in the European Union. This concept is reflected in the acronym IPCEI (“Important Project of Common European Interest”). Within the IPCEIs, projects work on activities along the entire battery value chain. This is reflected in the four funding priorities: raw materials and advanced materials, cells and modules, battery systems and repurposing, and recycling and sustainability.

Furthermore, through its battery initiative, the BMWE supports the continuous development of expertise along the entire battery value chain and ensures that research results are transferred more efficiently into industrial implementation. With the funding initiative "Research in the Priority Funding Program for Battery Cell Production," project consortia consisting of small and medium-sized enterprises, large corporations, as well as research and educational institutions are supported. These projects form an innovation base to facilitate industrial-scale battery cell production in Germany. The funding priorities focus on battery sustainability, including recycling, digitalization of production and lifecycle management, innovative testing and certification procedures, and the application of next-generation battery cell technologies. In addition, the BMWE supports the development of qualification measures and specifically involves regional clusters and educational institutions in the battery ecosystem.

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1. Sustainability of batteries, including recycling

1.1.1 Battery Passport – Battery Passport "Made with Germany": Implementation of a new generation of digital product handling (completed)

The Battery Pass consortium is making diverse contributions toward the implementation of the digital battery passport required by the EU Battery Regulation by February 2027, with its work continuing until early 2025. The project analyzes the content-related and technical requirements formulated by the European Commission, examines existing standards and architectural solutions, develops both a virtual and a physical demonstrator, and assesses the individual and systemic benefits for stakeholders qualitatively and quantitatively. By developing scientifically sound results that are supported by industrial partners and validated by civil society actors, the project ensures maximum acceptance and benefit. The project was completed in 2025.

Consortium leader:	**Partners:**
SystemiQ Deutschland GmbH Mühldorfstr. 8 81671 Munich https://www.systemiq.earth/	• Fraunhofer IPK • acatech e.V. • Circulor GmbH • BASF SE • FIWARE Foundation e.V. • Audi AG • BMW AG • UMICORE AG & Co. KG • TWAICE Technologies

The consortium intends to design cross-industry content-related and technical standards for a battery passport and to demonstrate them in a pilot project (TRL 5–7). The battery passport supports the sustainable and circular management of vehicle traction batteries by providing a digital infrastructure for documenting and exchanging essential information and update-relevant technical data. In particular, data comprehensively describing the sustainability and accountability of the supply chain—such as the GHG footprint, working conditions in raw material extraction, and battery condition assessment—will be documented.

By combining the expertise of the project participants, the consortium ensures that the results are scientifically and technically sound, industrially relevant, and suitable for the development of a global sustainable battery value chain. Members of the consortium include leading industrial companies from relevant sectors, research institutions and academies, as well as providers of digital services in open-source standards, battery analytics, and tracking and tracing. Coordination is carried out by a recognized organization specializing in system change toward more sustainable economic models.

The project group explicitly supports the principles for sustainable battery value chains formulated by the Global Battery Alliance (GBA). Through the involvement of the GBA as an associated partner, its preliminary

work is integrated, its broad network of members—including environmental and social organizations as well as global governmental organizations—is engaged, and the global applicability of the results is ensured.

The work packages include:

- Development and coordination of content-related standards, including CO_2 footprint, sustainable supply chains, circularity, battery condition assessment, liability transfer, and auditability
- Development and coordination of technical standards for open-standard and open-source applicability of the results
- Practical piloting of the results in a demonstrator (software and/or physical)
- Analysis of the added value of the battery passport in specific use cases and overall
- Coordination with national, EU, and global stakeholders (standardization organizations, industry and scientific associations, as well as governments)

1.1.2 BatteryPass-Ready – Test environment for the practical implementation of the battery passport

BatteryPass-Ready is developing a test environment that enables companies to verify the conformity of their digital product passport system with the required data completeness, structure, and formats, as well as to test and demonstrate the interaction between the components of the manufacturer, the IT service provider, and those of the European Commission.

Consortium leader:	**Partners:**
Fraunhofer IPK Pascalstraße 8 – 9 10587 Berlin https://www.ipk.fraunhofer.de	• acatech • GEFEG • TU Berlin

With the entry into force of EU Battery Regulation No. 2023/1542, digital product passports (DPP) will be mandatory from February 2027 for all batteries used to power electric vehicles and light means of transport, as well as for industrial batteries with a capacity of 2 kWh or more. A decentralized system is planned for this purpose, with interconnected components operated by the European Commission (registration), the manufacturer (decentralized data storage and provision), and IT service providers (backup).

Given the complexity and novelty of the overall project, the BatteryPass-Ready consortium is developing a test environment. This enables manufacturers and service providers to check their individual solutions for compliance with standards already during the development phase and to ensure that they are properly connected to the EU system.

The environment is intended to cover the following core functionalities, which would otherwise have to be developed individually by each provider:

- Definition of test procedures
- Analysis of ongoing developments regarding mandatory data points and generation of test data,

or inclusion of test data provided by users
- Execution, monitoring, and logging of tests
- Creation of emulation environments, particularly for components provided and operated by the European Commission (e.g., registry)
- Technical integration of the systems to be tested as well as the data source interfaces of the EU DPP system

The test environment will be used from a technical perspective (e.g., for interaction tests), for initial development, and for maintenance and expansion. Furthermore, testing will be carried out to ensure DPP compliance for new or updated solutions. In addition, the environment is intended to support the integration of partners in the value chain (e.g., repair workshops).

The work is carried out in close coordination with relevant stakeholders, such as the associated associations VDA, VDMA, ZIV, and BITKOM.

1.1.3 COBALT-P – Circular Open Battery Lifecycle Trading Platform

Through the development of a circular economy platform with an integrated trading platform, the current challenges of battery use and battery management are to be addressed. The goal of the project is to increase supply chain transparency and extend the service life of batteries through second-life applications, as well as to enable efficient recycling.

Consortium leader:	**Partners:**
Circunomics GmbH Große Bleiche 15 55116 Mainz https://www.circunomics.com/	• TES-AMM Central Europe GmbH • RWTH Aachen, Institut für Stromrichtertechnik und Elektrische Antriebe ISEA • Energy Web DevHub GmbH

The increasing demand for batteries driven by electromobility and renewable energies brings the challenge of sustainable resource management. As the most valuable yet most emission-intensive component of an electric vehicle, battery reuse and recycling are fundamental to achieving a green energy transition. Used EV batteries hold great potential for reuse in stationary energy storage systems, extending their service life by up to 15 years. However, the efficient implementation and profitability of second-life energy storage systems and recycling processes require improved planning and risk reduction through data collection and analysis.

The COBALT-P project aims to address current challenges in battery use and battery management by developing a circular economy platform based on predictive analytics, decision-making algorithms, and digital twins with blockchain technology, combined with an integrated trading platform. The key challenges include data intransparency within the supply chain, difficulties in matching supply and demand, system requirements and battery conditions leading to insufficient reliability of second-life energy storage systems, inefficient processes and trading procedures, and the absence of a second-life and recycling trading network.

To overcome these obstacles, the project partners Circunomics, TES, Energy Web, and RWTH Aachen have joined forces to develop a model-based decision-making platform that enables predictive trading of used

lithium-ion batteries using lifetime predictions and automated matching, thereby optimizing their lifecycle. This approach will increase resource utilization efficiency while reducing reuse costs and emissions.

1.1.4 EarLi – Extraction and purification of lithium hydroxide monohydrate from used electric vehicle lithium-ion batteries for battery cell production

The joint project EarLi addresses sustainable lithium recovery in the context of recycling lithium-ion batteries. For this purpose, the partners are developing and implementing an innovative process chain on an industry-relevant scale, in which lithium is selectively extracted from the active material and purified into high-purity lithium hydroxide monohydrate using electrolytic membrane filtration.

Consortium leader:	**Partners:**
ACCUREC-Recycling Gesellschaft mbH Bataverstr. 21 47809 Krefeld https://accurec.de/	• RWTH Aachen, Institut für Metallurgische Prozesstechnik und Metallrecycling • Evonik Operations GmbH • Öko-Institut e.V.

To date, no industrially implemented process exists for recovering lithium from used lithium-ion batteries. Laboratory-scale concepts have failed in large-scale implementation, primarily due to economic competition with primary metallurgical lithium production. With rising lithium prices (approximately +1,000% over the past two years) and regulatory pressure mandating lithium recovery starting in 2026, the rapid development and scaling of innovative processes that meet economic and ecological requirements is urgently needed.

Against this backdrop, the EarLi consortium aims to scale up a process chain successfully validated at the laboratory level to an industry-relevant scale, enabling sustainable lithium recovery with minimal resource and energy consumption. The specifically developed pyrolysis technique allows for selective lithium extraction using neutral leaching solutions, completely eliminating the need for additives. From the purified solution, lithium can then be directly recovered as high-purity lithium hydroxide monohydrate through an electrochemical process using a lithium-ion selective membrane. This product can once again serve as a raw material for the production of lithium-ion battery cells. Another distinctive feature of the EarLi process chain is the recirculation and purification of the leaching solution, resulting in an extremely efficient overall process

1.1.5 HVBatCycle – HV battery recycling and resynthesis processes for sustainable and function-preserving material cycles

The HVBatCycle project aims to develop sustainable and energy-efficient processes along the value chain of HV batteries to enable a closed-loop circulation of battery materials. The project will investigate processes for automated disassembly, ecological recycling of end-of-life batteries, and the production of new battery materials from the recovered secondary raw materials, while also demonstrating their scalability and economic viability.

Consortium leader:	**Partner:**
PowerCo SE Industriestraße Nord 38239 Salzgitter https://www.powerco.de/	• TU Braunschweig, Institut für Hochspannungstechnik und Energiesysteme • TU Braunschweig, Institut für Chemische und Thermische Verfahrenstechnik • TU Braunschweig, Institut für Partikeltechnik • TU Braunschweig, Institut für Energie- und Systemverfahrenstechnik • TU Braunschweig, Institut für Werkzeugmaschinen und Fertigungstechnik • TANIOBIS GmbH • J. Schmalz GmbH • RWTH Aachen, IME Metallurgische Prozesstechnik und Metallrecycling • Fraunhofer-Institut für Schicht- und Oberflächentechnik IST

The “HVBatCycle” project has the overarching goal of developing and gaining a deeper understanding of innovative, sustainable, and energy-efficient processes along the value chain of high-voltage batteries from electric vehicles, in order to enable the closed-loop circulation of battery materials in the near future. In particular, the project will investigate processes for clean disassembly, ecologically efficient recycling of end-of-life batteries, and the production of new battery materials from the recovered secondary raw materials, while demonstrating their scalability and economic viability.

Building on various previous projects carried out by the participating partners, the project will present new and further developments, examining how and with what financial and technical effort the requirements of the new EU legislation regarding the material recycling of Li-ion batteries can be met—and even exceeded—by 2030. Through an interdisciplinary and highly qualified consortium, innovative processes for a connected end-to-end value chain will be developed, researched, and transferred from the laboratory to a prototypical implementation across numerous core areas of expertise.

In addition, the project will assess whether the produced secondary materials are suitable for reuse in battery cells as part of multiple recycling loops. Furthermore, prior to the recycling process, a battery analysis will be conducted to pre-sort incoming batteries with regard to their potential for second-life applications.

1.1.6 Li-GeReKo – Lithium: Extraction, Recycling, Concentration

The project consortium, consisting of MionTec GmbH and TH Köln, is pursuing the goal of developing innovative and sustainable processes for the extraction and recovery of lithium for use in lithium-ion batteries (LIBs) through the combination of ion exchange and membrane processes within the project Lithium: Extraction, Recycling, Concentration (Li-GeReKo).

Consortium leader:	**Partners:**
MionTec GmbH Ernst-Bloch-Str. 8 51377 Leverkusen https://miontec.de/	• Technische Hochschule Köln, Fakultät für Anlagen, Energie- und Maschinensysteme

The project consortium, consisting of MionTec GmbH and TH Köln, is pursuing the goal of developing innovative and sustainable processes for the extraction and recovery of lithium for use in lithium-ion batteries (LIBs) through the combination of ion exchange and membrane processes within the project Lithium: Extraction, Recycling, Concentration (Li-GeReKo).

The project addresses two main areas: lithium extraction from brines and lithium recovery from LIB recycling. In lithium extraction from brines, the investigated processes aim not only to recover lithium but also to return the extracted groundwater instead of losing it through the evaporation process typically used today, thereby minimizing further drying of the affected regions. In lithium recovery from LIB recycling, the technologies under investigation aim to ensure a higher recycling rate for lithium and serve as innovative process steps to optimize recycling processes, including the treatment of potential wastewater streams.

The current Technology Readiness Level (TRL) of 3–4 is to be increased to TRL 7 through the development and construction of a container-based demonstration plant. This plant will consist of separate modules for selective lithium extraction and concentration using ion exchange and membrane processes and will be tested in field trials.

In addition to TH Köln's academic use of the results in research and teaching, MionTec plans to market the results through the rental and sale of container-based pilot plants, along with process engineering consulting for the design and operation of such systems for relevant operators and plant manufacturers. In the case of developing a patentable process, licensing to implementing companies is also planned.

1.1.7 LIBERATION – Solution-based liberation and reintegration of functional battery materials from production scrap in cell manufacturing

The LIBERATION project addresses the pressing issue of processing production scrap from lithium-ion battery manufacturing. Following successful preliminary investigations, the experienced consortium partners propose a novel, differentiated processing route for anode and cathode scrap, enabling the reuse of product materials at the highest process level.

Consortium leader:	**Partners:**
ACCUREC-Recycling Gesellschaft mbH Bataverstr. 21 47809 Krefeld https://accurec.de/	• Fraunhofer-Institut für Verfahrenstechnik und Verpackung (IVV) • CTG GmbH & Co. KG • Öko-Institut e.V.

Outside of media focus, the ramp-up of announced production capacities for lithium-ion batteries (LIBs) brings with it a largely unaddressed problem that significantly affects the sustainability of cells: the generation and resource-efficient handling of production scrap from cell factories. Currently, no industrially scalable processing concept exists for the waste generated at different stages of cell manufacturing. As a result, these materials can only be fed into conventional secondary raw material recycling routes, recovering valuable metals at the elemental level. This approach involves high effort and considerable material losses (e.g., the complete loss of high-quality battery graphite), which rightly conflicts with political and societal demands regarding resource and energy efficiency as well as CO_2 emissions, while also requiring significant operating resources.

The LIBERATION research project tackles this issue by focusing on the industry-oriented implementation of a solution-based process for the liberation and reintegration of functional battery materials from production scrap in cell manufacturing. Using specially developed solvents with highly selective properties, the binders are specifically dissolved without altering the relevant chemical, physical, or electrochemical functions of the active materials. As a result, the functional materials become directly available in high-quality form for reintegration into the LIB value chain or alternative high-tech applications. Consequently, the sustainability of LIBs is substantially improved, as the energy- and resource-intensive refining process for elemental metal recovery is avoided.

1.1.8 LiBinfinity – Development of a holistic and sustainable recycling approach for lithium-ion batteries

Designing a circular economy for lithium-ion batteries through a holistic approach to the process from economic and ecological perspectives — from developing a logistics concept to creating an industrial-scale recycling process and reintegrating the recovered materials into the production of new batteries.

Consortium leader:	**Partners:**
Mercedes-Benz AG Mercedesstr. 120 70372 Stuttgart https://group.mercedes-benz.com/de/	• Daimler Truck AG • Primobius GmbH • SMS-Group GmbH • Technische Universität Clausthal IFAD • Karlsruher Institut für Technologie • Technische Universität Berlin, Institut für technischen Umweltschutz

The goal of the LiBinfinity project is to develop a holistic and sustainable recycling approach for lithium-ion batteries (LIBs) that is a European leader from both ecological and economic perspectives, enabling a true circular economy for battery materials through innovative process design. To achieve this, a mechanical-hydrometallurgical process is being developed that—uniquely—completely eliminates energy-intensive and resource-consuming pyrometallurgical process steps. Through this process design and an end-to-end approach—from developing logistics concepts to reintegrating recycled materials into the battery lifecycle—a comprehensive strategy will be created and implemented in a prototype application via the construction of a pilot plant.

A particular feature of this project is the direct integration of hydrometallurgy, which is currently unique across Europe but serves as a core element in realizing sustainable battery recycling within a circular economy. By optimizing leaching, extraction, and separation processes within the hydrometallurgical framework, the project aims to achieve material recovery rates of >95% for nickel and cobalt and >70% for lithium, thereby exceeding the requirements of the EU Battery Directive. Additionally, further optimization

possibilities and future potential of the process will be explored, such as investigating graphite recycling to battery-grade quality and transferring the approach to alternative cell chemistries like lithium iron phosphate (LFP).

A unique aspect of this project is its holistic approach, which includes the direct reintegration of recycled materials into the production cycle. For this reason, the re-synthesis of new active material from recycled materials—including the assembly of new cells and their electrochemical characterization—is also addressed. These efforts are complemented by dedicated sustainability assessments, including a life cycle analysis (LCA) focused on CO_2 footprint, as well as investigations into energy requirements and resource criticality.

1.1.9 LiFe cycle - Lithium iron phosphate and lithium iron manganese phosphate circularity: From raw material to valuable resource

In the LiFe cycle project, the chemical industry, together with the automotive industry, aims to establish the foundations for improved iron-based cathode materials based on LFP or manganese-containing LFP (lithium iron manganese phosphate, LFMP), while taking into account the necessity of raw material circularity from the very beginning

Consortium leader:	**Partners:**
LANXESS Deutschland GmbH Kennedyplatz 1 50679 Köln https://lanxess.com/de-de	• Mercedes Benz AG

A technological shift in public transportation is imminent, moving from internal combustion engines powered by fossil fuels to electrified drivetrains fueled by lithium-based batteries. This shift is driven, among other factors, by the major challenges of climate change and the need to reduce the global CO_2 footprint. Accordingly, various industries are working with focus and motivation to make this technological transition as energy- and resource-efficient as possible from the outset. To successfully achieve this shift in drivetrain technology, a wide range of materials for battery production must be made available and sourced under ecologically and ethically acceptable conditions.

An essential and resource-intensive component of the lithium-ion battery is the cathode. The cathode serves as the lithium source for the battery and consists of metal oxides. Iron-based cathode materials are environmentally friendly, cost-effective, durable, and safe. Thanks to the enhanced safety of lithium iron phosphate (LFP), the construction of vehicle battery packs can forgo modular designs, allowing similar power densities at the pack level compared to nickel-cobalt-manganese (NCM) batteries.

In the LiFe cycle project, the chemical industry, together with the automotive industry, aims to lay the foundations for improved iron-based cathode materials based on LFP or manganese-containing LFP (lithium iron manganese phosphate, LFMP) and to directly establish the circularity of the cathode material.

The LiFe cycle project takes a holistic approach to cathode material management from the outset, incorporating the necessity of raw material circularity as a fundamental principle

1.1.10 NMC-Direct – Development of a prototype for the direct production of environmentally friendly (re)generated pre-CAM from black mass

For the “NMC-Direct” project, four key German stakeholders from different areas of the battery material cycle have joined forces to develop a holistic approach for processing and reconditioning battery materials. The core of the project is the development of a prototype that, for the first time, directly produces cathode active material from black mass and scales up the results previously achieved at the laboratory or pilot level.

Consortium leader:	**Partner:**
Königswarter & Ebell Chemische Fabrik GmbH Im Ennepetal 19-21 58135 Hagen https://purebatterytech.com/ke-germany/	• Westfälische Wilhelms-Universität Münster MEET

For the project “Development of a Prototype for the Direct Production of Environmentally Friendly (Re)Generated Pre-Cathode Active Material (pCAM) from Black Mass” (“NMC-Direct”), four key German stakeholders from different areas of the battery material cycle have joined forces to develop a holistic approach for processing and reconditioning battery materials.

The core of the project is the development of a prototype that, for the first time, directly produces cathode active material from black mass (nickel-, manganese-, and cobalt-containing cathode active material) and scales up the results previously achieved at the laboratory/pilot level (up to TRL 5). The prototype enables resource-efficient chemical direct recovery of pCAM (a nickel-manganese concentrate “NMC”), primarily from the processing of black mass, without the need to separate individual metal fractions.

Following the prototype construction, the project aims to verify the recycling process from end-of-life batteries to new batteries in continuously operating plants at the project partners’ facilities. A series of test campaigns will be carried out, transferring prepared material into the chemical processing stage of the prototype. The directly produced pCAM will then be further processed into battery cells and tested for performance. The focus will be on identifying and addressing process engineering bottlenecks and optimizing (interfaces) regarding product quality, process costs, and environmental impacts (particularly the CO_2 footprint).

1.1.11 ReAktiv – Highly efficient recycling of Li-ion active materials from cylindrical and button cells

The “ReAktiv” project addresses, on one hand, a significant improvement in the recycling process for cylindrical cells and the reconditioning of the recovered active materials without generating black mass. Furthermore, it aims to demonstrate the reintegration of these active materials into new battery cells. On the other hand, the project revises and optimizes a process based on black mass from button cells to enable the recovery of the contained lithium metal.

Consortium leader:	**Partners:**
K-UTEC AG Salt Technologies Am Petersenschacht 7 99706 Sonderhausen https://www.k-utec.de/home	• acp systems AG • ACI systems GmbH • TU Bergakademie Freiberg, Institut für Mechanische Verfahrenstechnik und Aufbereitungstechnik • Universität Stuttgart, Institut für Photovoltaik • Fraunhofer-Institut für Produktionstechnik und Automatisierung IPA • Fraunhofer-Institut für Solare Energiesysteme ISE • Fraunhofer-Einrichtung für Wertstoffkreisläufe und Ressourcenstrategie IWKS

The “ReAktiv” project addresses, on one hand, a significant improvement in the recycling process for cylindrical cells and the reconditioning of the recovered active materials without generating black mass. It also aims to demonstrate the reintegration of these active materials into new battery cells. On the other hand, a process based on black mass from button cells is being revised and optimized to enable the recovery of the contained lithium metal.

Cylindrical cells, mostly originating from production scrap, are first disassembled, and the contained anodes and cathodes are separated by type. After detaching the active materials from the electrode foils, these materials are cleaned and, if necessary, reprocessed in further steps. The properties of this recycled material are intended to be comparable to virgin material, which will be demonstrated by producing new cells with a recycled content and subsequently characterizing them. In parallel, the insights gained will be transferred into a battery cell model using a hybrid model, so that by the end of the project, a model for recycled-material-based cells will be available as a design tool. Additionally, an economic and ecological assessment of the new process chain will be carried out.

By combining the expertise of industry and academia, the targeted innovations can be grouped into five key points:

1. The disassembly of cylindrical cells for the separate recovery of anodes and cathodes;

2. The development and testing of process steps for the recovery of high-quality, single-grade anode and cathode materials;

3. The development of a cell model as a planning tool for characterizing the performance of recycled-material-based cells, taking into account the specific properties of recycled active materials; and

4. The construction, testing, and benchmarking of recycled-material-based cells. In parallel,

5. the efficient recovery of lithium metal from black mass is being investigated.

1.1.12 REVAMP – Remanufacturing of diverse battery modules with automated assembly and testing processes

The core aspect of the project is the development of a versatile remanufacturing system for condition assessment, disassembly, reconditioning, reassembly, and testing of end-of-first-life batteries from commercial vehicles. Concrete results are to be validated through demonstration plants at the application partners' sites. Another key aspect is the evaluation of the economic viability of the second-use/second-life business model for commercial vehicle batteries.

Consortium leader:	**Partners:**
MAN Truck & Bus SE Dachauer Str. 667 80995 München https://www.man.eu/corporate/en/homepage.html	• BE-Power GmbH • Weidemann GmbH • Wacker Neuson Produktion GmbH & CO. KG • Bertrandt Technikum GmbH • Software AG • Safion GmbH • IBG Automation GmbH • RWTH Aachen, Fakultät Maschinenwesen - Werkzeugmaschinenlabor (WZL) • Frauenhofer-Institut für Produktionstechnologie (IPT)

The REVAMP research project addresses the challenges of second-use and second-life applications for commercial vehicle battery systems. Within the project, a flexible, automated remanufacturing system with reliable condition assessment—based on a digital twin—is being developed, alongside an economically viable and sustainable business model for OEMs.

The goal of the project is to increase the utilization rate of second-use and second-life batteries in Germany through cost-effective, automated, and flexible remanufacturing. Potential second-use or second-life scenarios include their use as spare parts for used vehicles or commercial vehicle bodies, stationary energy storage systems, decentralized energy supply, or autonomous transport systems.

Thanks to the broad expertise of the project partners, the consortium is able to cover the entire battery lifecycle—from production and first-life usage, including data provision, to reconditioning and second-use applications.

1.1.13 SUVEREN2Use – Extinguishing systems and emergency response concepts for the safe handling of battery fires

The goal of the project is to contribute to fire safety across the entire battery value chain through technical developments and to address existing gaps in guidelines and standards with its own contributions. New technologies for fire detection and suppression, as well as for handling damaged batteries, are to be developed.

Consortium leader:	**Partners:**
FOGTEC Brandschutz GmbH Schanzenstr. 19 A 51063 Köln https://fogtec-international.com/de/home.html	• Lobbe Entsorgung West GmbH & Co KG • Fraunhofer-Institut für Nachrichtentechnik – Heinrich-Hertz-Institut • Bergische Universität Wuppertal | Fakultät für Maschinenbau und Sicherheitstechnik

The success of the energy and mobility transition depends on the comprehensive use of new energy carriers, particularly batteries. So far, there are hardly any technical solutions or corresponding standards to manage the fire safety risks associated with batteries. The goal of the SUVEREN2Use research project is to establish the necessary fire safety measures across the entire battery value chain.

The SUVEREN2Use project builds on the results of its predecessor project SUVEREN (BMBF, 2017–2020), which focused on the impact of new energy carriers in vehicles on safety in underground transportation facilities. This previous project provided important insights that are now being applied at a practical level, with the research focus extended to the entire lifecycle of batteries.

The topic of “safety” is the main focus of the three work areas:

- Development of fire protection solutions (technologies for fire suppression) for various stages of the battery value chain inside and outside vehicles, including production facilities and energy storage systems.
- Development of a battery-integrated extinguishing system for use in larger vehicles such as trucks, buses, and trains, as well as in energy storage systems.
- Development of emergency response concepts for battery fires, including guidance for proper disposal.

The industry-led research consortium, consisting of companies active in various areas of the battery value chain (FOGTEC/fire protection; technotrans/automotive Tier-1 supplier; Lobbe/disposal and emergency management), is supported scientifically by the University of Wuppertal and the Fraunhofer Heinrich Hertz Institute. Through new technologies for fire detection and suppression as well as actionable recommendations for planners, manufacturers, emergency responders, authorities, and disposal companies, the project aims to improve safety throughout the entire value chain.

1.1.14 TropMelt – Dry powder melt calendaring for environmentally friendly and cost-efficient electrode production

The TroPMelt project brings together research and industry to achieve more sustainable, resource-efficient, and thus cost-effective electrode production in Europe through an efficient, innovative, and dry extrusion-based electrode coating method.

Consortium leader:	**Partners:**
UniverCell Holding GmbH Konrad-Zuse-Ring 1 24220 Flintbek https://www.univercell.group/de	• Fraunhofer-Institut für Siliziumtechnologie, Fraunhofer ISIT • Fraunhofer-Institut für Fertigungstechnik und Angewandte Materialforschung IFAM • Brabender GmbH & Co. KG

TroPMelt aims to establish continuous, extrusion-based dry coating of anode and cathode materials for electrode production at European manufacturing sites, focusing on sustainability, innovation, and process optimization.

To achieve this, project partners from research and industry are collaborating to jointly overcome challenges in developing such a coating system. Using a newly designed pilot demonstrator plant, state-of-the-art electrodes as well as experimental high-energy anodes will be produced.

Subsequently, the materials produced will be used to manufacture high-performance, high-energy cells. This project therefore represents an important step toward future series production of battery cells using extrusion-based dry electrode coating methods, while simultaneously assessing the technological feasibility.

1.1.15 Truckified Battery - Development of novel and innovative production processes and methods in battery cell manufacturing

The research project aims to develop novel and innovative production processes and methods for electric vehicle batteries. These will be developed in collaboration with German and European plant engineering companies in the areas of electrode manufacturing, cell assembly, and cell finishing/testing, and subsequently validated. The project is further complemented by elements of cognitive production and the integration of intelligent sensor systems with hybrid process models, leading toward a sovereign data ecosystem.

Consortium leader:	**Partners:**
Daimler Truck AG Hanns-Martin-Schleyer-Straße 21 68305 Mannheim https://www.daimlertruck.com/	/

As part of the research and development project “Truckified Battery,” Daimler Truck AG plans to industrially research novel and innovative production processes and methods for its own electric vehicle batteries. These processes will be developed in collaboration with German and European plant engineering companies, focusing on electrode manufacturing, cell assembly, cell finishing, and comprehensive testing (at both the cell and overall system level), and will be validated in a small-series production facility.

In cooperation with academic institutions, the project will be complemented by elements of cognitive production and the integration of intelligent sensor systems with hybrid process models, moving toward a sovereign data ecosystem. During industrial research, and considering the availability of materials, the first recyclates will already be incorporated into the cell chemistry and assessed regarding their impact on the production process.

The insights and experiences gained from this project are intended to support future large-scale industrialization of battery cell production in Europe.

With the project objectives:

- Use of European coating technologies, primarily in the field of dry coating;
- Optimization of the “notching” process and redesign of the “stacking process” (prismatic form factor);
- Improvements in “electrolyte filling”;
- Reduction of scrap rates in existing production through the integration of intelligent sensor systems and hybrid process models;
- Rapid qualification of processes and machinery to enable commissioning during ongoing operations (when scaling up series production facilities);

the European battery value chain, as well as the resilience and sustainability of the battery cell manufacturing ecosystem, is to be strengthened.

Over the course of the project, which spans four years, an average of more than 40 FTEs will be employed, and additional investments exceeding €30 million will be made.

1.1.16 VALUE-M – Extending the usable lifespan of storage systems through micro-cycle operation with continuous condition monitoring

The “VALUE-M” project explores opportunities for resource-efficient and profit-enhancing use of battery storage systems in the energy sector, particularly so-called “second-life systems.” The main goals are: extending the lifespan of existing battery cells through optimized micro-cycle operation, developing and adapting suitable testing methods that support individually optimized, life-preserving operation, and creating management methods that extend battery life and thus enable higher long-term returns.

For the project, various established as well as new storage technologies, including second-life storage systems, will be examined regarding their use within such a storage swarm. After developing an algorithm for swarm control, a demonstration system will be designed and operated.

Consortium leader:	**Partners:**
Siemens Aktiengesellschaft Werner-von-Siemens-Str. 1 80333 München https://www.siemens.com/de/de.html	• RWTH Aachen, Institut für Stromrichtertechnik und Elektrische Antriebe ISEA • SWW Wunsiedel GmbH

In the future, power grids will face a significantly increased need for short-term balancing mechanisms, particularly in the form of power and frequency regulation. Key focus areas include providing instantaneous reserves and managing continuous intraday trading. These applications place diverse requirements on energy storage systems. Available battery storage technologies always involve a trade-off between high-power variants, systems with high energy density, or particularly robust cycle stability.

This is where the research project comes in. Energy storage systems of different technologies are to be controlled in swarms. An algorithm will determine which storage unit or combination of units can meet a given requirement while optimizing operating costs, based on the requested energy and power.

For the project, various established and new storage technologies, as well as second-life storage systems, will be examined for their suitability in such a swarm operation. Following the development of the swarm control algorithm, a demonstration plant will be designed and operated.

1.1.17 VaTreBat – Variant-flexible and automated separation of connections in the disassembly process of battery systems

The VaTreBat project is developing a process for automated and variant-flexible separation down to the cell level to increase flexibility, safety, and productivity in the disassembly of battery systems. The focus is on automated classification of joints and components, the development of a separation process, and the creation of a universal gripping system.

Consortium leader:	**Partners:**
Ansmann AG Industriestr. 10 97959 Assamstadt https://www.ansmann.de/	• Technische Universität Braunschweig, Institut für Werkzeugmaschinen und Fertigungstechnik • Technische Universität Braunschweig, Institut für Füge- und Schweißtechnik • J. Schmalz GmbH • Redux Recycling GmbH • SITEC Industrietechnologie GmbH

In the recycling process of battery systems, a disassembly stage precedes mechanical and chemical processing. This step is essential for recovering reusable components and increasing both the purity and quantity of recyclable materials. Since the economic and ecological value of a battery system is primarily tied to its cells, condition-based separation into reusable and recyclable cells is crucial.

Due to the current lack of standards, battery systems exhibit high variance, making disassembly processes labor-intensive and heavily dependent on manual work. To enhance flexibility, safety, and productivity, the VaTreBat project is developing a process for automated and variant-flexible disassembly of battery systems down to the cell level. For the required separation of numerous types of joints, laser and waterjet cutting processes are being designed. These processes can universally, contactlessly, and minimally invasively cut joints even in confined spaces.

The separation process is complemented by a universal gripping system that securely fixes and removes the separated components using variant-flexible grippers. For automated, robot-based execution of cutting and gripping operations, 3D image processing methods based on machine learning are being developed. These enable variant-flexible detection and classification of joints, as well as categorization of separated components. This allows for autonomous, adaptive sequence and trajectory planning with dynamic collision avoidance.

The process control, combined with the cutting process and gripping system, will be implemented in a demonstrator process and evaluated regarding the quality of the disassembled components, safety, cost-effectiveness, industrial scalability, and achievable work and process safety (including fire protection).

1.1.18 ZeroCaLi – CO_2-neutral extraction of lithium hydroxide monohydrate (LHM) from geothermal LiCl solutions

The goal of ZeroCaLi is to enable the economic and CO_2-neutral extraction of lithium hydroxide monohydrate (LHM) from geothermal brine through the further development and optimization of process engineering systems. LHM is an essential raw material for the production of battery cells for electric vehicles. This represents an important contribution to CO_2-neutral battery manufacturing and thus to achieving the EU's goals for climate neutrality and reducing dependency on critical raw material–supplying countries.

Consortium leader	**Partners:**
Vulcan GmbH Amalienbadstr. 41 76227 Karlsruhe	/

The goal of the ZeroCaLi project is to enable the economic and CO_2-neutral extraction of lithium hydroxide monohydrate (LHM) from geothermal brine through optimized process engineering systems. This essential raw material for the production of battery cells for electric vehicles is intended to be extracted in the Upper Rhine Graben.

The project focuses on two key steps of the innovative extraction process: the extraction of a lithium chloride solution from geothermal brine and the electrolysis of this solution into the final LHM product. Climate neutrality is achieved by powering the process with renewable energy from the geothermal plants that produce the thermal water. To make the process economically viable, it is necessary to optimize its energy efficiency, as well as the yield and product quality.

As part of the project, an optimization plant for extraction and an optimization plant for electrolysis will first be commissioned. The subsequent process optimization of both plants represents a multidimensional optimization problem with numerous parameters and multiple target variables, for which modern data processing methods and artificial intelligence (AI) will be applied. This requires collecting a large amount of data from the test operation of both plants. Using newly developed algorithms, a model will be created that can predict and apply improved operating parameters. In an iterative process, the model will then be validated and refined to ultimately achieve optimal operating conditions.

The insights gained in the project will subsequently be used to implement the entire process on an industrial scale. The CO_2-neutral extraction of a raw material essential for the mobility transition in Germany represents an important contribution to achieving the EU's goals for climate neutrality and reducing dependency on critical raw material suppliers.

2. Digitalization of production and lifecycle

1.2.1 ExElPro – Data-driven product and process optimization in high-variant electrode manufacturing

Lithium-ion battery cells are increasingly being used in niche markets. For these specialized applications, new battery cell technologies must be repeatedly developed to meet application-specific requirements and produced in small quantities cost-effectively while maintaining high quality.

To bring a new technology to a production-ready standard, even with the use of advanced experimental design methods, a large number of time-consuming and resource-intensive trials are still required—particularly for the mixing and coating process steps.

The goal of the project is to determine the optimal parameterization of the mixing and coating processes for different electrode formulations in relation to electrode quality and to reduce the number of experimental runs needed for functional prototypes—specifically in slurry preparation—by more than 50%. To achieve this goal, methods of artificial intelligence and digital twins will be utilized.

Consortium leader	**Partners**
Customcells Itzehoe GmbH Fraunhoferstr. 1b 25524 Itzehoe https://customcells.com/	• Amorph Systems GmbH • Capgemini Engineering Deutschland S.A.S. & Co. KG • Fraunhofer IPA

Lithium-ion battery cells are increasingly being used in niche markets. For these specialized applications, new battery cell technologies must be repeatedly developed to meet application-specific requirements and produced in small quantities cost-effectively while maintaining high quality.

To make this possible, fast and efficient development cycles are essential. However, bringing a new technology to a production-ready standard still requires a large number of time-consuming and resource-intensive trials—particularly for the mixing and coating process steps—even when using advanced experimental design based on the current state of the art.

The goal of the ExElPro project is to determine the optimal parameterization of the mixing and coating processes with respect to electrode quality for various electrode formulations. Additionally, the number of experimental runs required to produce functional prototypes for electrode slurry preparation is to be reduced by more than 50%.

To achieve this, the complex interrelationships between production conditions and product properties will be made transparent and quantifiable using artificial intelligence methods.

The foundation for applying these data-driven technologies will be created through the development of process digital twins, which will be supplied with product, process, machine, and context data based on an end-to-end Industry 4.0 topology. These digital twins can thus be seamlessly integrated into the business process, from order intake to the finished prototype.

1.2.2 HOBAZELL – Digitalized, sustainable high-speed battery cell production

The project aims to develop and set up a fully automated, novel cell manufacturing system. Prototype battery cells will be produced to characterize product traceability, process data monitoring, and predictive condition monitoring within the framework of a smart factory.

Consortium leader:	**Partners:**
MB Automation GmbH & Co. KG Josef-Mühlbauer-Platz 1 93426 Roding https://www.muehlbauer.de/	• Zentrum für Sonnenenergie-und Wasserstoff-Forschung Baden-Württemberg (ZSW) • M. Braun Inertgas-Systeme GmbH

Under the coordination of Mühlbauer GmbH & Co. KG, together with partners M. Braun Inertgas-Systeme GmbH and the Center for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW), as well as the associated partner Cellforce Group, the project "Digitalized, Sustainable High-Speed Battery Cell Production – HOBAZELL" aims to develop a sustainable, gigafactory-capable battery cell manufacturing process. The overall goal is to significantly reduce costs, increase throughput by a factor of 2.5, and improve the quality and efficiency of the final product.

To achieve this, the currently limited process speeds in the stacking process are to be multiplied within the smallest possible required space. In addition, a highly efficient, fast, and space-saving filling process will be developed and implemented. The costly energy demand of the relevant production environments is to be significantly reduced through a higher degree of automation, process chaining, and micro-environment solutions.

To ensure quality, continuous quality monitoring using vision systems and sensors will be implemented. Within the framework of an efficient "smart factory," the project also focuses on product traceability of the manufactured components. By digitally documenting process data from the manufacturing of individual components and consolidating it in a database, resource consumption will be further reduced, and the CO_2 footprint will be minimized.

1.2.3 MultiFlow – Sustainable and cost-effective redox flow battery technology for stationary storage

This development will focus on vanadium redox flow batteries and related flow battery technologies that use carbon felts as electrodes.

Consortium leader:	**Partners:**
Siemens Energy Global GmbH & Co.KG Otto-Hahn-Ring 6 81739 München https://www.siemens-energy.com/de/de/home.html	• Optima life science GmbH • acp systems AG • Leister Technologies Deutschland GmbH • Whitecell Eisenhuth GmbH & Co. KG • Fraunhofer-Institut für Chemische Technologie ICT

This development focuses on vanadium redox flow batteries (VRFBs) and related flow battery technologies that use carbon felts as electrodes.

A roll-to-roll/roll-to-piece approach is intended to significantly reduce cycle times and transform what is currently mostly semi-automated or manual production into large-scale manufacturing. To illustrate: in manual production, output is measured in "plates per shift," whereas in mass production, it is measured in "meters per shift" or "square meters per shift," with a much smaller workforce. Transitioning from manual to web-based production can increase manufacturing capacity by approximately a factor of five. In addition, automated production ensures reproducible quality, independent of operator influence, resulting in a reliable process. The developed automation will be incorporated into the “digital twin” of the roll-to-roll/roll-to-piece process for flow batteries. Furthermore, a digital twin will be created for two process steps—the stacking process and the roll-to-roll/roll-to-piece process—and these will be integrated.

Life Cycle Assessment (LCA), eco-design, and techno-economic modeling will ensure a CO_2-efficient and energy-saving production process as well as appropriate recycling strategies. These manufacturing technologies have the potential to massively reduce the costs of redox flow batteries and establish these stationary storage systems—which do not rely on scarce battery metals—as a cornerstone of the energy transition.

For the planned expansion of renewable energy and to achieve the German government’s climate goals, implementing energy storage systems that can supply electricity over multiple time scales is essential. Battery storage is the most flexible solution for applications requiring storage over several hours.

Redox flow batteries (RFBs) are expected to be among the most cost-effective solutions for multi-hour renewable energy storage, as they can provide long lifespans at comparatively low costs when production facilities are scaled appropriately. For example, vanadium RFB systems (VRFBs) are estimated to have levelized costs of storage (LCOS) of 380–400 €/MWh (K.E. Rodby, 2020). However, conventional VRFBs still have payback periods that are too long for large-scale commercial deployment. Contributing factors include not only high production costs but also low profit margins from typical arbitrage, making it difficult to operate these storage systems profitably in Germany. As a result, these batteries are currently mainly used in niche applications or foreign markets. To enable broader market integration, the costs of these systems must be significantly reduced. For VRFBs, there is a cost floor dictated by the production costs of the vanadium electrolyte, currently set at 60–80 €/kWh due to vanadium prices.

However, the high cost of VRFB electrolytes can be mitigated through leasing models. This is feasible because the electrolyte retains residual value at the end of its service life, which can be redeemed—similar to established precious metal leasing practices. To further reduce system costs, the “MultiFlow” project comes into play. Siemens Energy, together with industrial partners and several Fraunhofer institutes, aims to produce the performance component—the so-called stack—more sustainably and cost-effectively using advanced roll-to-roll manufacturing techniques and digital optimization of quality-critical process steps. Cost savings will be consistently pursued through the utilization of all economies of scale, supported by new technologies. While some companies in Germany are already investing in production technologies for redox flow battery stacks, there is still a lack of highly automated production systems to fully leverage large-scale efficiencies.

The use of new digital technologies can help minimize costs and resource consumption in RFB stack production. In the MultiFlow project, novel production processes for stack frames will be combined into a model using a digital twin, and cycle times will be optimized. Fast roll-to-roll and roll-to-piece processes will be developed to reduce manufacturing cycle times and thus lower costs. Resource consumption will be analyzed using methods such as Life Cycle Assessment (LCA) and Life Cycle Cost Analysis (LCC), correlating them with costs to find an optimal balance between ecology and economy. This includes end-of-life strategies for recycling. Feeding these insights back into the initial product design—an approach known as eco-design—will be a consistent practice in the project. A cloud-based predictive maintenance concept will complement the production design for large-scale manufacturing.

Using the production techniques developed on test machinery and the process models in the "digital twin," including the cloud-based predictive maintenance concept, investments in fully automated production can be made with reduced risk. This will help companies in key sectors, such as Siemens Energy, take the necessary steps to reshape their technology portfolio for the energy transition and remain competitive in an international market. Furthermore, by incorporating sustainability considerations into production design, the project promotes circularity. Redox flow batteries, in particular, offer excellent conditions for material separation and cost-effective recycling strategies due to their modular design and consistent use of plastics such as polyethylene and polypropylene. In the MultiFlow project, this circular approach will be integrated and redefined throughout the entire stack manufacturing process, combining economy and ecology with the help of digital technologies.

1.2.4 ProMoBatt – Process modeling for the optimization of battery cell manufacturing

Through the development of digital twins, relevant components of the stacking process will be analyzed and optimized. Based on these models, a highly productive stacking system will be designed and implemented.

Consortium leader:	**Partners:**
Jonas & Redmann Automationstechnik GmbH Segelfliegerdamm 65 12487 Berlin https://www.jonas-redmann.com/	• BST GmbH • J.Schmalz GmbH • Carl Zeiss Industrielle Messtechnik GmbH • Custom Cells Itzehoe GmbH • Karlsruher Institut für Technologie, wbk Institut für Produktionstechnik • Technische Universität Berlin, Institut für Werkzeugmaschinen und Fabrikbetrieb IWF • Hochschule Aalen, Institut für Materialforschung IMFAA

The interrelationships within the production processes of battery cell manufacturing are still not fully understood. This issue continues to pose a barrier for Germany as a production location to efficiently and economically manufacture battery cells in high volumes for the global market. Both the development and provision of the necessary production machinery, as well as their commissioning and operation, are affected by this challenge.

In particular, the cell stacking process step offers high potential for optimization within the overall context of battery cell production. As part of the ProMoBatt project (Process Modeling for the Optimization of Battery Cell Manufacturing), this process step is being systematically and sustainably optimized by a consortium of key stakeholders from science and industry through the development of high-performance process models.

On this basis, the project aims to develop new, innovative technical solutions in the areas of web guiding, gripping and handling technologies, and quality assurance, which will then be applied within a dedicated system setup.

3. Innovative testing and certification procedures

1.3.1 E-LAS+ - Development of a multimodal in-line inspection method for the use of adaptive laser welding processes

In the e-LAS+ project, an acoustic in-line inspection method for laser welding of battery cells is being developed, along with an AI-based platform to enable the cost-efficient operation of laser welding systems, even for smaller batch sizes. Predictive process adjustment is also a central focus of the developments, aiming to create a multimodal inspection method. To achieve this, the entire value chain is being improved, and the practical experience of machine operators is systematically collected and integrated.

Consortium leader:	**Partners:**
NeuroControls GmbH Tal 44 80331 Munich https://neurocontrols.io/	• NeuroControls GmbH (Projektkoordination) • Fraunhofer-Institut für Digitale Medientechnologie IDMT • SSI Software Services GmbH • SITEC Industrietechnologie GmbH • VRI GmbH Batterie Technik

Laser welding is of enormous importance for safety-critical applications in aerospace, medical technology, and other fields. In the field of electromobility, it is already being used for large-scale battery production. The challenge in laser welding lies in achieving optimal heat input through the laser to create a reliable weld connection while avoiding damage to the cell. Currently, determining the optimal process parameters for welding requires a highly complex, iterative process with numerous destructive tests.

The goal of the e-LAS+ project is to make laser welding economically viable even for smaller batch sizes (1–100,000 units). This requires significant developments along the value chain at both the machine and laser process levels, as well as in measurement and inspection methods: (1) development of an adaptive laser welding process; (2) development of a multimodal in-line inspection method; (3) development of a digital assistance system; and (4) construction of a pilot plant/demonstrator.

The in-line inspection method developed in e-LAS+ for laser welding is intended to enable both predictive and corrective process adjustments. On a digital platform, process settings for future welding operations will be documented and intelligently adjustable during production. In this way, machine operators will also be supported by a digital assistance system. At the same time, operator experience will be captured qualitatively through a simple method to document this expert knowledge and make it usable for future process optimizations. These developments are also designed to be transferable to other application fields.

The multimodal in-line inspection method and the knowledge management system with the corresponding assistance system will be demonstrated in a pilot plant. After project completion, the plant and associated systems are expected to reach series production readiness within approximately one year, enabling a market launch by early 2027.

1.3.2 GRISU – Novel testing methods and innovative fire protection measures for the development of large batteries

The goals of the GRISU research project are, on the one hand, to reduce the risk of large-scale fires during standardized safety tests in test laboratories for electromobility batteries, and on the other hand, to further develop testing procedures by demonstratively building test environments that cover the necessary acceleration and frequency ranges.

The demonstrators built as part of the project will continue to be used after the funding period ends.

Consortium leader:	**Partners:**
Messring GmbH Friedrichshafener Str. 4c 82205 Gilching	• Linxens GmbH • Fraunhofer-Institut für Solare Energiesysteme ISE • Hochschule für Angewandte Wissenschaften Hamburg

The goal of the GRISU research project is to reduce the risk of large-scale fires during standardized safety tests in test laboratories for electromobility batteries and to further develop testing procedures.

As part of GRISU, test-compliant and effective fire protection measures are being developed to counteract the use of low-cost, sacrificial test infrastructure in the event of damage. Furthermore, the project addresses the advancement of novel testing methods for realistic testing of large-scale vehicle floor batteries. In particular, the previously unconsidered use and bending of battery packs with their resonance amplification will be represented on an innovative vibration test stand. The higher risks of fire damage associated with this must be effectively mitigated using suitable fire protection technologies.

The project aims to create an appropriate testing environment with realistic external loads to cover the necessary acceleration and frequency ranges of mechanical stress for large vehicle floor batteries weighing around 750 kg. The vibration test stand poses numerous challenges, such as bending and twisting of the vehicle floor under realistic interface impedances and degrees of freedom, with high-frequency excitation quality reaching the nanometer range.

By combining these two approaches and addressing the mentioned challenges, generally applicable methods for controlling fire risks will be demonstrated for laboratory operations, and the transfer of these solutions to various applications will be enabled. It is of central importance that novel testing methods can only be meaningfully implemented once a verified fire protection concept is in place.

The demonstrators developed within the collaborative project, including passive fire protection solutions, will be built at the partners' facilities during the project period, ensuring continued use of the equipment after the funding project ends. Through the partners' involvement in standardization committees and numerous publications, the results and findings will be made available to a broad public.

1.3.3 HealthBatt – Efficient and integrated sensor technology for intelligent, sustainable, and safe battery systems

In the HealthBatt research project, battery storage systems will be equipped with sensors in a multi-unit setup to enable longer operating times and second-use strategies. Recording and analyzing the load history allows for a more accurate assessment of the battery system's condition compared to conventional systems. This gain in information makes it possible to better estimate the service life, reduce unexpected failures, and individualize intervals between repairs and maintenance. These improvements benefit both manufacturers and users.

Consortium leader:	**Partners:**
VARTA Storage GmbH Nürnberger Str. 65 86720 Nördlingen https://www.varta-ag.com/de/	• Infineon Technologies AG (IFX) • Technische Universität München, Institut für Werkzeugmaschinen und Betriebswissenschaften IWB • Fraunhofer-Institut für Silicatforschung ISC

The electrification of conventional drivetrains has been identified as a key element of efficient and sustainable mobility within the German Federal Government's National Electromobility Development Plan.

In many applications, however, the product life cycle of a battery system ends when it reaches a state of health (SoH) of 80%. For economic reasons, such storage systems are in most cases sent for recycling rather than continued use. From a sustainability perspective, this leaves considerable untapped potential, as these systems could be repurposed for second-use applications, such as storing electricity generated from wind or photovoltaic energy. Given their proximity to residential areas and the high number of charge cycles required in such applications, ensuring the safe operation of energy storage systems is essential.

Through a multi-sensor approach and intelligent data processing, this research project aims to holistically identify the load profile (temperature, shocks, vibrations, etc.) of a battery system within the framework of condition monitoring. In a suitable module concept developed by VARTA, a sensor unit will be integrated that covers a comprehensive spectrum of physical measurement data. The newly developed storage system is intended for use in stationary and/or mobile battery storage systems for agricultural applications and will therefore be exposed to significant vibrations.

Measurement data relevant to cell aging will be pre-filtered for more efficient analysis. These load profiles will then be correlated with the status and remaining lifespan of the battery system using physical aging models and artificial intelligence methods. A "traffic light" system will be used to assess whether a safety-critical fault is present. The remaining lifespan can then serve as the basis for deciding whether the battery system is suitable for second-life applications or should be sent for recycling. This decision will be displayed clearly and unambiguously through the integrated traffic light visualization.

To effectively investigate a comprehensive and easily integrable sensor system in combination with reliable remaining lifetime prediction, a large dataset and specific expertise across various fields are required. These include reliable and robust measurement of physical states, production engineering experience for the electrical integration of sensor technology, knowledge of aging and defect mechanisms in electrochemical energy storage systems, as well as expertise in information technology and artificial intelligence (AI).

1.3.4 LiPi – Rapid testing and assessment of lithium plating for performance improvement and increased operational safety of lithium-ion batteries

In this project, a rapid test is being developed to characterize the tendency of lithium-ion cells to form lithium plating and to evaluate it with respect to safety aspects. This will not only enable the comparison of different products but can also be used in the development of lithium-ion cells for optimization purposes.

Consortium leader:	**Partners:**
BatterieIngenieure GmbH Hüttenstr. 5 52068 Aachen https://batterieingenieure.de/en/home/	• TU Berlin - Fachgebiet Elektrische Energiespeichertechnik

Lithium plating is not only an aging mechanism that leads to one of the fastest degradations of cell capacity and poses a safety risk due to dendrite formation, but it is also one of the key obstacles to achieving short charging times, e.g., in electric vehicles. Plating is caused by high currents and low temperatures—both conditions to which electric vehicles are regularly exposed in everyday operation. In addition, the process depends on the aging state of the cell.

Therefore, for battery cell manufacturers, it is essential to assess cells regarding their plating characteristics before they are put into use, in order to define safe operating limits. However, this characterization requires extensive measurements and involves significant time and cost.

To reduce the effort and cost of these measurements and to standardize the results, this project aims to develop a method for a rapid test that can characterize a cell's plating behavior cost-effectively and with minimal time investment. The results of this rapid test will provide a plating index, allowing for straightforward comparison of different cells regarding their plating behavior.

The resulting plating index will include boundaries such as the maximum charging current or temperature range for the safe operation of the cell without plating risk, as well as a safety assessment of the cell concerning its plating behavior. The availability of this rapid test is expected to lead to shorter development times and, through improved operational parameters, to an extended service life of the cells in use.

1.3.5 Longer – Lifetime-optimized, intelligent battery storage systems

The Longer project aims to significantly improve the lifespan and profitability of home energy storage systems through a modern operating strategy. The software tools developed within the project will make it possible to individually adjust charging and discharging management based on customer usage behavior. VARTA Storage coordinates this development with leading partners from industry and academia to implement a practical application on field test devices of the "VARTA.wall" type.

Consortium leader:	**Partners:**
VARTA Storage GmbH Nürnberger Str. 65 86720 Nördlingen https://www.varta-ag.com/de/	• TWT GmbH Science & Innovation • Fraunhofer-Institut für Solare Energiesysteme (ISE) • NOVUM engineerING GmbH

Using modern data analysis methods, various usage scenarios of stationary energy storage systems are being investigated in a practical manner to generate the most accurate possible load forecasts. Such forecasts are necessary to align system operation with the specific usage scenario.

In a further step, field data and advanced AI technologies are used to assess the “State of Health” (SOH) of the battery modules. The goal is to predict the impact of different load scenarios and use these predictions as input for a lifetime-optimized operational strategy.

The findings will be incorporated into an operational management algorithm and integrated into a home storage system developed by VARTA Storage. Currently, there are no reliable laboratory evaluation procedures for forecast-based controls. Therefore, the project aims to develop optimal test profiles that enable early error detection in the lab and reduce testing effort.

By the end of the project, the results will be verified through a simplified (accelerated) field test and a simulation model using the developed methods. A demonstrator will be built to assess which measures at the system and module level can be practically transferred to series production.

1.3.6 METABatt - Automated and reproducible modeling of the electrical, thermal, and aging behavior of batteries

The METABatt project is creating an automated and reproducible testing process in which battery cells are measured electrically, thermally, and with respect to aging behavior, the measurement data is evaluated, and models in the corresponding domains are parameterized. This testing process will enable users to start an automated procedure at the push of a button and obtain a battery model that can be used for simulations or algorithms.

Consortium leader:	**Partners:**
Digatron Power Electronics Tempelhofer Str. 12-14 52068 Aachen https://www.digatron.com/de-de/	• RWTH Aachen, Institut für Stromrichtertechnik und Elektrische Antriebe, Lehrstuhl für Elektrochemische Energiewandlung und Speichersystemtechnik (ISEA) • Safion GmbH • BatterieIngenieure GmbH

The METABatt project is creating an automated and reproducible testing process in which battery cells are electrically, thermally, and aging-specifically measured, the resulting data is evaluated, and models in the respective domains are parameterized. The planned demonstrator will enable users to start this process at the push of a button and receive a battery model that can be used for simulations or algorithms—without requiring in-depth expertise. This approach can generate significant time and cost savings for OEMs, suppliers of new battery cells, and for optimizing cell production processes, thereby accelerating product development. Such battery models are also an essential component for system design, operational strategies, and performance evaluation of applications such as electric vehicles, making them a key resource for many industry stakeholders.

The project's objectives will be addressed through advancements and innovations at multiple stages of the model creation chain. On one hand, test equipment will be enhanced to conduct more efficient, precise, and automated battery tests. On the other hand, innovative concepts will be developed to enable reproducible testing setups and workflows—focusing on reliable electrical contacting and maintaining defined test conditions throughout the entire testing period.

Integrating innovative measurement techniques into this automated process is a fundamental part of the project, allowing for faster and more accurate data collection for model parameterization. A requirement-specific test plan, aligned with standardized procedures for battery testing, will be developed. Finally, the recorded data must be evaluated, and model parameters identified. Automating this process requires standardizing battery tests, which also enables comparability across different batteries.

The identified parameters, in combination with all recorded data, can be analyzed and correlated to identify and quantify battery aging effects. With the support of machine learning and artificial intelligence, the entire set of tested samples can additionally be analyzed and evaluated regarding various quality characteristics.

1.3.7 Quaze – Development of a self-learning method for quality determination in battery cell production

Defects in battery cells can reduce their lifespan and compromise safe operation, making early detection crucial. Existing non-destructive methods often fail to adequately detect critical defects or provide insights into their location and cause.

The Quaze research project aims to develop an innovative, non-destructive testing method for precisely measuring local volume changes in battery cells during cycling. The goal is to enable the localization of battery defects as early as possible in the production process using this new testing approach.

The method is based on spatially resolved detection of mechanical changes in battery cells and complements the conventional electrical characterization. This enhances both the quality and safety of battery cells. Early defect detection in production can significantly reduce scrap rates, saving costs and improving the environmental sustainability of battery technology.

Consortium leader:	**Partners:**
Precitec Optronik GmbH Schleussnerstr. 54 63263 Neu-Isenburg https://www.precitec.com/de/	• Fraunhofer-Institut für Solare Energiesysteme ISE • Precitec GmbH & Co. KG

Defects in battery cells can reduce their lifespan and compromise safe operation, making early detection essential. Current non-destructive testing methods often fail to adequately detect critical defects and frequently do not allow conclusions about their location.

The research project “Development of a Self-Learning Method for Quality Determination in Battery Cell Production Based on Optical Thickness Measurement – Quaze” aims to develop an innovative, non-destructive testing method for precisely measuring local volume changes in battery cells during cycling. The goal is to enable the localization and quantification of battery defects as early as possible in the production process using this new method.

The approach is based on spatially resolved detection of mechanical changes in battery cells and complements conventional electrical characterization. This significantly improves the quality and safety of battery cells. Early defect detection in production can greatly reduce scrap rates, saving costs and improving the environmental sustainability of battery technology.

Within the project, various commercial battery cells will be comprehensively tested under different cycling parameters, generating large amounts of measurement data. These data will be used to develop models with machine learning methods, particularly deep learning techniques, to make predictions about aging progression. These methods, combined with highly accurate point measurements, enable substantial improvements in current quality assessments and lifetime predictions.

The innovative AI-supported measurement methods will provide important new insights into the relationship between defects and volume changes in battery cells, going far beyond the current state of knowledge. The involvement of industrial partners from battery manufacturing accelerates the transfer of results into practice.

1.3.8 SAMBA - Scanning Acoustic Microscopy-basierte Batterie-Analyse

As part of the SAMBA research project, an ultrasound-based non-destructive testing method for examining battery pouch cells in quality assurance is being established. Using Scanning Acoustic Microscopy (SAM), image data of the cell interiors are generated and subsequently analyzed through an automated evaluation routine. For this purpose, a self-learning algorithm is implemented to detect, classify, and localize defects. This enables the acquisition of important information regarding the root causes of failures. To validate the method, both cells with intentionally introduced defects and intact samples are examined. The characterization results are compared and evaluated against conventional analysis methods.

Consortium leader:	**Partners:**
PVA TePla Analytical Systems GmbH Deutschordenstr. 38 73463 Westhausen https://www.pvatepla.com/	• Fraunhofer-Institut für Solare Energiesysteme ISE • Microvast GmbH

Acoustic microscopy is a widely used testing method for the non-destructive detection of delaminations, cracks, and voids in materials, as well as in electronic components. The goal of the SAMBA project is to use Scanning Acoustic Microscopy (SAM) to non-destructively detect mechanical defects in battery cells that are either electrically undetectable or only slightly measurable due to overlapping signals.

The objective of the SAMBA project is to overcome these challenges and implement a SAM-based analysis method that significantly increases throughput in the quality assurance of battery cells. To achieve this, the project plans the following steps:

- Construction of a SAM test stand with sufficient lateral resolution to detect defects in the micrometer range within pouch cells.
- Ensuring adequate penetration of the acoustic wavelength without critical energy loss to enable complete examination of the pouch cell across its entire cross-section. For this purpose, both phased arrays and transmission measurements will be used.
- Detection of measurement artifacts such as multiple reflections and their correct interpretation. The measurement process is intended to be attractive for industrial use by ensuring short testing times at overall low costs, achieved through optimized measurement parameters and increased sensor head speed.

1.3.9 SimDural – Simulation of the safety risks of uncontrolled thermal runaway in aged cells

The project aims to develop an integrated workflow for simulation-based safety assessment of uncontrolled thermal runaway in aged battery cells. This workflow consists of an innovative combination of experiments and simulations, ranging from the molecular level to the entire cell. After the project's completion, the project partners will be able to further develop the workflow or individual steps into commercially available products and/or services.

Consortium leader:	**Partners:**
Bayerische Motoren Werke Aktiengesellschaft Petuelring 130 80809 Munich https://www.bmw.de/de/home.html	• EL-Cell GmbH • Karlsruher Institut für Technologie, Institut für Angewandte Materialien - Elektrochemische Technologien • SGS Germany GmbH • Siemens Industry Software GmbH • TU Braunschweig, Institut für Partikeltechnik

The steadily increasing range requirements for electric vehicles result in higher cell energy densities. One of the greatest challenges remains ensuring the current level of safety, particularly for cells with increased energy density. At present, it is nearly impossible to implement a reliable safety assessment for aged cells during the early design phase.

The main objective of the SimDural project is to develop a simulation-based workflow for assessing the safety of uncontrolled thermal runaway in aged battery cells. As part of the research project, cells will be built and then deliberately aged, after which they will be disassembled for chemical analysis. For the simulations, reaction equations, reaction kinetics, electrolyte evaporation, and short circuits will be modeled. This will involve a combination of molecular-level calculations, the Discrete Element Method (DEM), and continuum modeling with electrochemical and thermodynamic models.

Experiments for parameterizing these models will be conducted on laboratory and pouch cells, including the development of a specialized testing device for determining gas products. Abuse cases will be simulated using a proprietary physical full-cell model and a multiphysics 3D model with homogenized electrode layers. An essential part of the project is the repeated validation of simulations for various abuse cases across different cell aging states.

The consortium aims to develop a workflow that combines experiments and simulations in such a way that it can be completed within 3 months. This will allow the workflow to be used, among other applications, in the early phases of the development process to optimize cell design timelines.

1.3.10 SUSTAIN – Damage and condition analysis of defective high-voltage batteries

As part of the project, a prototype diagnostic device will be developed that, based on a damage catalog and using machine learning methods as well as model-based condition diagnostics, can analyze an unknown lithium-ion battery system. From this analysis, the device will generate a hazard assessment and an evaluation of the overall condition.

Consortium leader:	**Partners:**
Ferchau Automotive GmbH Steinmüllerallee 2 51643 Gummersbach https://www.ferchau.com/de/de	• ACCUREC - Recycling GmbH • Voltavision GmbH • Rheinische Hochschule Köln gGmbH, Fachbereich Ingenieurwesen • Hochschule Aalen, Institut für Materialforschung IMFAA • Technische Hochschule Ingolstadt

For an efficient, cross-sector energy transition, it is essential to consider the entire lifecycle and implement circular economy principles. A resource-efficient circular economy must use energy and materials effectively, and processes need to be designed as efficiently as possible. However, such process design requires prior knowledge. Batteries, whether after an accident or prolonged use, are often in an unknown or only partially known state regarding their remaining capacity or potential hazard. To handle these batteries optimally in terms of reuse, transport, or storage, innovative testing and certification methods—or digitalization of the lifecycle—are required.

The SUSTAIN project focuses on lithium-ion batteries. The main goal is the economic assessment of potentially damaged and thus disposable battery packs using a testing device to be developed. A distinction will be made between defective batteries that pose no hazard and can therefore be transported and stored for disposal without significant safety measures, defective batteries that do pose a hazard and thus require special safety precautions, and batteries that are still usable, either in their original application or in a second-life application.

The device will be developed with a user-oriented approach, involving both a recycling company and a laboratory operator to ensure practical applicability.

4. Application of next-generation battery cell technologies

1.4.1 3D-Si-Elektrode – Development of manufacturing technology for a fabric-based three-dimensional silicon electrode

The research consortium "3D-Si-Electrode" aims to develop a coating process for producing mechanically and structurally stable fabric-based three-dimensional silicon electrodes for rechargeable lithium-ion batteries (LIB), which will provide significantly extended lifespan and improved cycle stability.

Consortium leader:	**Partners:**
elfolion GmbH Quedlinburger Str. 14 06485 Quedlinburg https://elfolion.de/	• Technische Universität Bergakademie Freiberg • Institut für experimentelle Physik • VARTA Microbattery GmbH

The goal of the project is to develop a vacuum-based process for manufacturing fabric-based three-dimensional silicon anodes for secondary lithium-ion batteries (LIBs). These anodes are designed to mechanically and structurally compensate for the expansion and contraction effects that occur during cell charging and discharging (lithiation/delithiation), thereby significantly improving the lifespan and cycle stability of LIB cells in a sustainable way.

The solution involves replacing the copper foils typically used in current state-of-the-art technology with a fabric-based current collector consisting of copper as the conductive layer and a highly porous, corrosion-resistant graphite layer composed of fractal structures deposited onto the conductive layer. To achieve this, the technology for creating fractal solid structures on silicon (Si) will be adapted to produce structural elements ≤0.3 µm. These Si structures will ensure loss-free lithiation/delithiation.

The intended process will reach a pre-production maturity level within the project by incorporating existing roll-to-roll vacuum coating processes for current collectors. This approach will enable a more efficient, resource-conserving, and sustainable LIB technology by reducing the copper content by a factor of 6 to 10. Furthermore, the use of silicon electrodes aims to increase electrode storage capacity by a factor of 4 to 7 and overall cell capacity by a factor of 2 to 4 compared to the current state of the art.

1.4.2 3DPrintBatt – Sustainable, flexible additive manufacturing technology for sodium-ion solid-state batteries

The project is developing an innovative solid-state battery concept based on sodium (Na), eliminating the use of cobalt (Co) and lithium (Li), with the objective of producing the cell components using additive, printing-based manufacturing methods. Another key focus is the development of multimodal battery-specific analytics (in-line and at-line) and related equipment. In this context, several entirely new and highly innovative analysis and preparation techniques for battery development will be specifically advanced.

Consortium leader:	**Partners:**
Carl Zeiss Industrielle Messtechnik GmbH Carl-Zeiss-Str. 22 73447 Oberkochen https://www.zeiss.de/messtechnik/home.html	• Varta Microbattery GmbH • Leica Microsystems CMS GmbH • Intego GmbH • db-matik GmbH • Horiba Europe GmbH • Fraunhofer-Institut für Fertigungstechnik und Angewandte Materialforschung IFAM • Fraunhofer-Institut für Keramische Technologien und Systeme IKTS • Fraunhofer-Institut für Schicht- und Oberflächentechnik IST • TU Braunschweig, Institut für Partikeltechnik • Institut für Nanotechnologie und Mikroskopie GmbH INAM

In the 3DPrintBatt project, an innovative solid-state battery concept based on sodium (Na), eliminating the use of cobalt (Co) and lithium (Li), is being developed with the aim of producing cell components using additive, printing-based manufacturing methods. Another focus is the development of multimodal, battery-specific analytics (in-line and at-line) and related equipment. In this context, several entirely new and highly innovative analysis and preparation techniques for battery development will be specifically advanced.
The development work is carried out in coordinated development tracks:

- LabTrack: Development of analytics and sample preparation technology
- DigiTrack: Digitalization of processes in material and process simulations
- EcoTrack: Development of methods for assessing the usability of solid-state batteries in a circular economy with a controllable CO_2 footprint, including evaluation through life-cycle assessment (LCA)
- FabTrack: Recipe development for manufacturing sodium-based batteries using screen printing for application in commercial battery cell production in a potential pilot plant.

1.4.3 KOLIBRI – Development of sustainable components for lithium-ion batteries

The "KOLIBRI" project focuses on improving the sustainability and recyclability of lithium-ion batteries. Expensive raw materials, such as graphite, are replaced with secondary raw materials (recovered carbon black) to develop an innovative, sustainable anode material. At the same time, the electrolyte requires significantly less fluorine, which substantially reduces the environmental impact of batteries.

Consortium leader:	**Partners:**
RCB Nanotechnologies GmbH Ludwigstr. 11 80539 Munich https://recovered-carbon-black.com/	• Fraunhofer-Institut für Bauphysik IBP • Deutsches Zentrum für Luft- und Raumfahrt e.V. • UniverCell Holding GmbH • Zeppelin Systems GmbH

One of the core objectives of the "KOLIBRI" project is to develop a sustainable and innovative anode material for lithium-ion batteries to enable the use of secondary raw materials and improve the recyclability of the cells. Currently, graphite used in anodes is a key component of batteries. However, both the production of synthetic graphite and the mining of natural graphite have a number of negative environmental impacts.

The project therefore aims to substitute the graphite used and manufacture the anode material based on an aerogel using highly purified recovered carbon black (rCB) as a secondary raw material.

The company RCB currently achieves the highest purity levels of recovered carbon black. To enable the substitution of graphite, the current rCB purity of 96–98% must be increased to around 99%. It is crucial to maintain, and ideally increase, the porosity and surface area of the recovered carbon black during purification. In addition, the recyclability of the anode material is to be significantly improved.

Therefore, RCB, together with its partners, is working on refining the rCB purification process to provide highly pure rCB, developing and building the corresponding plant technology for the production of individual components, and scaling up the developed processes and components to an industrial level.

1.4.4 PEAk-Bat – Innovation in testing methods and development for effort reduction in future structural battery systems

The goal of the PEAk-Bat project is to develop new structural battery concepts and reduce the effort required for safety validation, certification, and homologation. The project involves the development of battery demonstrators, methods for virtual validation, and guidelines for safety tests aimed at certification and homologation.

Consortium leader:	**Partners:**
Ford-Werke GmbH Henry-Ford-Str. 1 50735 Köln https://www.ford.de/	• Advanced Car Technology Systems GmbH & Co. KG • RWTH Aachen, Production Engineering of E-Mobility Components • SCIO Technology GmbH • TRUMPF SE + Co. KG • TÜV Rheinland Automotive Component Testing GmbH

In the project "Innovation in Testing Methods and Development for Effort Reduction in Future Structural Battery Systems – PEAk-Bat," innovations are being developed in the areas of development, validation, certification, and homologation of novel electric vehicles to reduce product development efforts and the CO2 footprint of batteries.

The PEAk-Bat research project follows two parallel approaches. On one hand, innovative product concepts are being investigated in terms of design and manufacturing. On the other hand, the high validation and prototype costs of a battery are addressed through targeted virtual, non-destructive validation of batteries within the vehicle model development environment.

Ford focuses on three key points. The first point, with the support of partners, is the conceptualization of a cell-to-pack approach based on the current structure of a vehicle. The second point is Ford's involvement in building and validating a demonstrator. Both of these points relate to the product-oriented approach. A third and essential point involves virtual methods for validating battery safety and resistance to sudden external impacts. Through this point, Ford supports the approach of innovative testing methods.

1.4.5 Ultrabatt - Development of batteries with a gravimetric energy density of 300 Wh/kg using 3 mm thick electrodes (project completed)

The goal is to develop lithium-ion batteries with a high energy density of 300 Wh/kg using a novel manufacturing process for pressing 3 mm thick electrodes from a paste-like material mixture (metal powder, active material, high-boiling electrolyte, additives, and binders). By generating ideal interfacial layers (SEI, CDL), a remaining battery capacity of 85–90% after 5,000 cycles is achieved.

The project was completed in 2025.

Consortium leader:	**Partners:**
SOBEK Motorsporttechnik GmbH & Co. KG Badener Str. 8 69493 Hirschberg an der Bergstraße https://sobek-group.de/motorsports/	• Alfred Hermann GmbH & Co. KG • DORST Technologies GmbH & Co. KG • Universität Stuttgart Institut für Photovoltaik • Fraunhofer-Institut für Produktionstechnik und Automatisierung (IPA) - Zentrum für Digitalisierte Batteriezellproduktion

The goal of the research and development project is the development of Li-ion batteries with high energy densities of approximately 300 Wh/kg using a novel manufacturing process. For this purpose, a mixture consisting of active material, high-boiling electrolyte, additives, and binders is prepared and compacted. Subsequently, the pre-pressed component is placed into half-shells and joined by cold pressing. This makes it possible for the first time to produce thicker electrodes (~3 mm) compared to the conventional coating process (<0.3 mm). The aim is to develop a long-lasting product with a residual capacity of 85%–90% of the initial capacity after 5,000 cycles.

This is to be achieved through an optimized formation process for creating ideal interfacial layers, such as the Solid Electrolyte Interphase (SEI) and Cathodic Decomposition Layer (CDL). The energy demand is to be significantly reduced compared to conventional processes. Eliminating toxic solvents such as N-methyl-2-pyrrolidone (NMP) makes the manufacturing process more environmentally friendly and energy-efficient.

Through a functional, ion-conducting solid separator and the use of high-boiling electrolytes, the safety compared to conventional Li cells is significantly improved. The separator is intended to be environmentally friendly by avoiding perfluorinated polymer membranes and safe through high temperature resistance, wettability, puncture resistance, and resistance to shrinkage. Furthermore, the development of a battery management system (BMS) with an integrated heating system for battery temperature control (20 °C–40 °C) is being carried out. The BMS regulates cell voltage, cell balancing, and temperature to achieve gentle operation and optimal efficiencies during charging and discharging. This increases the lifespan and leads to fewer necessary replacements of the energy carrier, thereby conserving resources and increasing environmental friendliness.

5. Qualification and training measures

1.5.1 ABAKOS – Building Battery Competence – Saarland

The transformation of the Saarland automotive region has begun. The shift toward electric drives, including battery-powered ones, must take place. Industrial implementation along this lifecycle needs to be established, which requires the corresponding competencies.

ABAKOS supports the transformation process in Saarland by identifying and evaluating industrial solutions worldwide along the entire lifecycle of battery cell production (from raw materials to recycling). From this, the competencies that future employees must possess—particularly in a highly automated environment in Germany—will be derived. To build and expand this economic sector, qualification measures and qualification profiles in battery cell production must be tested and scaled.

Consortium leader:	**Partners:**
Festo Lernzentrum Saar GmbH Obere Kaiserstr. 301 66386 St. Ingbert https://www.festo-lernzentrum.de/	• Hochschule für Technik und Wirtschaft des Saarlandes, Professuren für Wirtschaftsingenieurwesen (htw/WI), Internationales Logistikmanagement (htw/ILM) & Fertigungstechnik (htw/FT) und Continuing Educatlon Center Saar (CEO) • Cluster Autoregion e. V. • Universität des Saarlandes (UdS) mit dem Transfercentre Sustainable Electrochemistry (UdS/TSE) und den Lehrstühlen für Konstruktionstechnik (UdS/LKT), Funktionswerkstoffe (UdS/FuWe) & Fertigungstechnik (UdS/LFT) • Ford Werke GmbH • Woll Maschinenbau GmbH

The transformation of the Saarland automotive region has begun. The shift toward electric drives, including battery-powered systems, must take place. Industrial implementation along this lifecycle needs to be established, which requires the corresponding competencies.

The ABAKOS project (Building Battery Competence – Saarland) actively supports and accompanies the transformation process in Saarland. Under the leadership of the Festo Learning Center, a competent partner network of universities, automotive clusters, and other companies will develop solutions for the region.

The goal of the project is to provide demand-oriented qualification for employees in battery cell production, which will both support the establishment of battery manufacturers in Saarland and accompany the transformation of the automotive industry from combustion engines to electric vehicles. The industrialization of battery cell production along the entire battery lifecycle is still in its infancy:

From raw material extraction to production, assembly, maintenance, second-life applications, and battery recycling, there is a lack of both ecologically and socially acceptable as well as technically feasible industrial solutions. These solutions must be developed and implemented by appropriately competent and qualified employees. A particular challenge here is that the degree of automation in Germany and Europe must be significantly higher than, for example, in Asia or South America in order to remain economically competitive. This, however, also presents an opportunity to establish market leadership in various areas of battery cell production.

ABAKOS aims to identify and evaluate industrial solutions along the battery cell production chain as well as maintenance issues to determine which competencies future employees in these areas will need. From this, qualification profiles and training measures will be developed, tested, and evaluated within the project. These measures will then be made available for broader application, thereby initiating and accompanying this transformation process.

The project is planned for a duration of five years and will begin with the area of assembly. In the field of maintenance, workshops are already confronted with a wide variety of challenges. Gradually, all areas along the battery lifecycle will be addressed, offering a great opportunity to support and advance regional transformation while establishing a new, responsibly-oriented industry.

1.5.2 B3 Bayern – Promotion of qualification measures for battery cell production

The B3 Battery Education Network Bavaria develops qualification programs, measures for work processes, and offers for company training personnel. The goal is the qualification of personnel in the field of battery cell production. Practical modules and virtual learning units are being created to enable individual modular "learning journeys," ensuring tailored qualification. The program is developed by a total of nine technical and didactic partners based on the needs of regional companies. An expansion of the program (extension to components, multilingual or accessible content, etc.) is conceivable after the end of the project.

The B3 Battery Education Network Bavaria identifies the needs of companies and develops three qualification focuses based on them. These are short-term modules (Modul-Batt), work process-oriented measures (APO-Batt), and programs for company training personnel (Coach-Batt). To ensure a high level of practical relevance in the qualification programs, technical partners (universities or research institutions) and didactic partners (educational institutions) work together with the participating companies on the program.

In addition to practical modules, virtual learning units are provided via a learning management system (LMS). This enables individual, modular “learning journeys” closely aligned with company needs. The practical modules take place in learning laboratories. Through strong regional networking and regular exchange, it is ensured that the developed content can be used sustainably and is aligned with the actual needs of companies.

1.5.3 BatterieMD – Educational Alliance BateryMD Battery Ecosystem in Central Germany

The Educational Alliance BatteryMD is dedicated to the development and implementation of systematic, needs-oriented, and sustainable qualification concepts along the value chain of battery cell production in the states of Saxony, Saxony-Anhalt, and Thuringia (Central Germany, MD) in order to build a dynamic workforce that meets the competency and qualification requirements of future-oriented production processes across the entire value chain.

Consortium leader:	**Partners:**
Energy Saxony e. V. Tatzberg 47 01307 Dresden https://energy-saxony.net/	• Automotive Cluster Ostdeutschland GmbH • ELMUG Elektronische Mess- und Gerätetechnik Thüringen eG • Berufsfortbildungswerk Gemeinnützige Bildungseinrichtung des DGB GmbH • ERFURT Bildungszentrum gGmbH • Schweißtechnische Lehr- und Versuchsanstalt Halle GmbH • VHS-Bildungswerk GmbH, AWZ Gotha • Duale Hochschule Gera-Eisenach • Universität Erfurt FG Berufspädagogik und Weiterbildung • Fraunhofer-Institut für Keramische Technologien und Systeme IKTS

The goal of the project Educational Alliance BatteryMD – "Battery Ecosystem in Central Germany" is to establish the competence trio BatteryMD together with innovation clusters in the energy technology and automotive sectors, vocational training providers, and scientific institutions. Together, they aim to identify the current and future qualification needs of companies along the Central German value chain for battery cell production in the states of Saxony, Saxony-Anhalt, and Thuringia and, based on this, to develop, test, implement, and disseminate a systematic, needs-oriented, and sustainable qualification concept.

The approach takes place in three steps: The identification of qualification needs is based on a company survey and a systematic description of work and production processes along the value chain, grounded in company case studies and scientific projections that incorporate current technological development trends. The competence and qualification needs identified in this way are compared—together with social partners and relevant labor market stakeholders—with existing job profiles and workforce potentials, and strategies for sustainable workforce development in the region are developed.

On this basis, the consortium partners, together with additional partners, develop a qualification concept that includes tailored retraining and advanced training programs for job seekers and career changers, continuing education for employees, qualifications for trainers and managers, as well as counseling services for employees, job seekers, and the unemployed. The individual programs are piloted by educational institutions in cooperation with companies and systematically disseminated and implemented among companies and training providers.

1.5.4 KOMBiH - Competence Development for Battery Cell Production in the Capital Region

In the project Competence Development for Battery Cell Production in the Capital Region, competencies for employees in battery cell production processes within value chains are identified. Based on this, qualification programs for relevant target groups are developed, tested, and implemented. The overall goal of the project is to develop and establish competencies in companies for battery cell production in cycles – from raw materials to production, use, post-use, and finally recycling or reuse.

Consortium leader:	**Partners:**
Vereinigung für Betriebliche Bildungsforschung e. V. Gubener Str. 47 10243 Berlin https://ibbf.berlin/	• Berufsfortbildungswerk als gemeinnützige Bildungseinrichtung des DGB GmbH (bfw) • Brandenburgische Technische Universität Cottbus-Senftenberg, Fachgebiet Physikalische Chemie • Brandenburgische Technische Universität Cottbus-Senftenberg, Zentrum für wissenschaftliche Weiterbildung • Technische Universität Berlin, Institut für Werkzeugmaschinen und Fabrikbetrieb (IWF), Fachgebiet Handhabungs- und Montagetechnik (HAMSTER) • Technische Universität Berlin, Institut für Energie und Automatisierungstechnik, Fachgebiet Elektrische Energiespeichertechnik (EET)

The joint project “Competence Development for Battery Cell Production in the Capital Region – KOMBiH” is implemented by nine partners from research, education, and industry. By involving additional associated partners, the transfer of project results into the educational and business landscape is pursued from the outset. In the project, the necessary competencies for employees in battery cell production processes within value chains are first identified and systematized. Based on this, current qualification programs for relevant target groups are developed, tested, and implemented in the capital region. The overarching goal of the project is to develop and establish skills and competencies for battery cell production in cycles – from raw materials to production, use, post-use, and finally recycling and reuse – in companies in the Berlin-Brandenburg region.

For qualification and competence development, innovative development teams from education, research, and industry are formed to create and establish suitable continuing education structures. Their collaboration serves the rapid implementation of current research results in companies and will contribute to their utilization. By building competence in the field of battery production, the project makes a comprehensive contribution to strengthening resilient, future-oriented value creation in the metropolitan region, particularly through circular economy practices and the activities of SMEs.

1.5.5 QualiBattBW - Qualification Measures for the Battery Ecosystem Baden-Württemberg

The Battery Competence Trio aims to build a large and excellent base of skilled workers along the battery value chain. Qualification needs are determined with the involvement of industry to develop modular qualification components, which are then delivered to SME employees using innovative learning methods. Trials are conducted to further develop these components. In addition, a consulting concept and an event series are being developed.

Consortium leader:	**Partners:**
e-mobil BW GmbH Leuschnerstr. 45 70176 Stuttgart https://www.e-mobilbw.de/	• Bildungswerk der Baden-Württembergischen Wirtschaft e. V. • Technische Akademie für berufliche Bildung Schwäbisch Gmünd Fraunhofer-Institut für Arbeitswirtschaft und Organisation IAO • Fraunhofer-Institut für Produktionstechnik und Automatisierung IPA • Hochschule Heilbronn • Karlsruher Institut für Technologie (KIT) – KIT Batterietechnikum • Institut für Photovoltaik (ipv) der Universität Stuttgart • Technische Hochschule Ulm (THU) • Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW)

The project Qualification Measures for the Battery Ecosystem Baden-Württemberg – QualiBattBW focuses on the development and implementation of a Battery Competence Trio with a consortium of relevant stakeholders from research, education, and innovation networks in the battery sector in Baden-Württemberg. The goal is to sustainably strengthen the state of Baden-Württemberg and Germany by networking the stakeholders and building an excellent and sufficiently large base of skilled workers along the battery value chain.

The project is based on an analysis of qualification needs in the field of vocational training, conducted in close cooperation with industry. Building on this, modular qualification components are developed, tested, and evaluated with users such as SME employees. These components are content-wise aligned with the battery value chain, from cell chemistry to recycling, and provide both basic and advanced modules. A standardized consulting concept is being developed to support companies in needs assessment and implementation.

Furthermore, the involvement of industry and social partners throughout the entire project duration is ensured through a project advisory board, the partners' networks, and a newly designed event series. This guarantees broad and stable outreach to companies and employees. The aim is to analyze work processes along the value chain so that the developed qualification modules create tailored future-oriented qualifications and convey relevant and in-demand skills to employees using innovative learning methods. A sustainability concept ensures that the modules developed in the project continue to be used in training and further education. In addition, discussions with social partners will address how these qualification modules can be integrated into training programs.

1.5.6 QuW-LIB - Qualification and Further Training of Skilled Workers Along the Entire Value Chain of Sustainable Lithium-Ion Batteries

The joint project QuW-LIB supports overcoming the shortage of skilled workers in the lithium-ion battery industry by developing innovative qualification and further training programs in modular approaches along the value chain of battery cell production. An industry-oriented training facility, enhanced by digital tools such as VR and AR, will be established at Fraunhofer ISIT in Itzehoe, where the developed training programs will be conducted in a competency-based, efficient, and industry-aligned manner.

Consortium leader:	**Partners:**
Heinze Akademie GmbH Überseering 9 22297 Hamburg https://heinze-akademie.de/	• Heinze Akademie GmbH (Projektkoordination) • Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V. Fraunhofer Institut für Siliziumtechnologie (ISIT) • Customcells Itzehoe GmbH (CCH) • Erneuerbare Energien Hamburg Clusteragentur GmbH (EEHH)

A worsening shortage of skilled workers, a simultaneously planned massive expansion of production capacities for lithium-ion batteries to up to 400 GWh in Europe alone, the reduction of capacities as a result of structural change, for example in the combustion engine value chain of the automotive sector, as well as the lack of suitable qualification and further training concepts could lead to a serious bottleneck, if not even a crisis, for Germany as an industrial location.

The few existing cell manufacturers in Germany and Europe are currently forced to train their required personnel themselves or are able to poach already trained personnel from research institutions. However, this personnel is mostly active at the management level, or alternatively consists of scientists. For production facilities, however, a very large number of production workers are primarily needed.

Currently, there is no advanced continuing education (eco)system that, based on evidence from research and development, has developed competency profiles for production personnel and implemented them using modern and scalable qualification methods. The question of which professional profiles are particularly suitable for specialist work in this area, and whether this could result in an independent occupational field, has also not yet been clarified.

To close this gap, a high-profile consortium from education and training, research, industry, and cluster management has been formed to develop innovative, sustainable, transferable, and scalable qualification concepts for skilled workers in the field of lithium-ion batteries for Germany as an industrial location.

2 National projects within the industrial funding programs in the European framework – IPCEI and TCTF

1. Cells & modules

2.1.1 ACC – Kaiserslautern – IPCEI-Project

Company: The Automotive Cells Company (ACC) is a new enterprise that brings together the expertise of three major companies with highly complementary skills and experience: TotalEnergies/Saft, Stellantis, and Mercedes-Benz.

- Saft specializes in advanced battery technology solutions for industry, from design and development to production, customized adaptation, and service provision.
- Stellantis is a France-based multinational automotive company that manufactures vehicles for brands such as Peugeot, Citroen, DS, Opel, Fiat, Alfa Romeo, Lancia, Maserati, Chrysler, and Jeep.
- Mercedes-Benz is an internationally operating automotive company headquartered in Germany. Stellantis and Mercedes-Benz contribute over a century of European industrial expertise to ACC.

The Automotive Cells Company (ACC) aims to become the European market leader for automotive battery cells to enable clean and efficient mobility for all.

ACC's ambitions are:

- To be a highly innovative high-tech center of excellence.
- To be competitive in order to manufacture batteries for all vehicle classes at the lowest possible cost.
- To be clean & green for truly environmentally friendly mobility.
- To keep pace with the mobility transition and create jobs.

Company:	**IPCEI Workstreams:**
Automotive Cells Company (ACC) S.E. Opelkreisel 1 67663 Kaiserslautern https://www.acc-emotion.com/	• Cells & Modules

Projekt: KAISERSLAUTERN (D)
Combination of an R&D center with state-of-the-art production facilities. This plant will start operations in 2025 with 8 GWh and will be ramped up to a total capacity of 24–40 GWh.

2.1.2 Alumina – IPCEI-Project

Company: ALUMINA SYSTEMS has been active for more than 30 years in the field of vacuum-tight ceramic-metal and ceramic-ceramic components and is a recognized technology leader in this area. The company traces back to Siemens KPW (Ceramics and Porcelain Plant), founded in the 1970s. Alumina Systems products are used as critical components in various demanding applications and industries, as well as in laser, medical, and vacuum technology systems. At the end of 2015, Alumina Systems began its first activities in the field of sodium-nickel-chloride batteries (Na/NiCl2) by supplying brazed components for research projects. Its own activities eventually began in 2019.

Company:	**IPCEI Workstreams:**
Alumina Systems GmbH Bahnhofstr. 43 96257 Redwitz a. d. Rodach https://alumina.systems/	• Batteriesysteme • Zellen & Module

Project: The goal of the project is to develop a small production line to verify the technology, feasibility, and economic potential of Na/NiCl2 systems for the European industry.

Within this framework, the necessary production techniques for battery cell production and battery system production will be developed, and a proof-of-concept on an industrial scale will be demonstrated. In parallel, long-term tests of battery cells and assembled battery systems must be conducted to evaluate the impact of the production process on the properties of the cells and systems.

2.1.3 Cellforce Group – IPCEI-Project

Company: Cellforce Group GmbH was founded in 2021.

The primary goal of the company is to establish battery cell production capacities for high-performance cells for automotive applications in Europe. This aims to reduce the supply gap in the field of automotive applications as well as the knowledge gap between R&D and series production.

Company:	**IPCEI Workstreams:**
Cellforce Group GmbH Jopestr. 14 72072 Tübingen https://www.cellforce.de	• Cells & Modules

Project: The Cellforce Group's project aims to develop a high-performance battery cell that combines the best anode and cathode materials for the battery cell of the future. These cells will combine the need for high energy densities with the requirements for fast charging. In addition, a high-quality production line for these cells will be established, serving as a blueprint for later ramp-up phases. Within the project, world-class facilities and cutting-edge technologies will be used to manufacture a globally competitive cell product.

2.1.4 ElringKlinger AG – IPCEI-Project

Company: ElringKlinger is a major Tier-1 supplier for the automotive industry, employing around 10,000 people at 45 locations worldwide. The company has been developing products related to lithium-ion batteries since the early 2000s. Due to its experience in producing components for the automotive industry, the focus is on design for cost-effective mass production.

The company's core competencies (including sheet metal forming, injection molding, toolmaking, joining, coating, and assembly) make the housings of lithium-ion batteries (LIBs) a significant value-creation opportunity. In the area of cell housing components, ElringKlinger has expertise in seals, cell cover design and manufacturing, as well as experience in using lithium-ion cells for assembling battery modules and systems.

Company:	**IPCEI Workstreams:**
ElringKlinger AG Max-Eyth-Straße 2 72581 Dettingen/Erms https://www.elringklinger.com	• Cells & Modules

Projekt: ElringKlinger will contribute to a competitive European battery value chain through the development and industrialization of an innovative cell housing design. The new design reduces the number and complexity of components in cell housings as well as the consumption of energy-intensive raw materials such as aluminum and copper. In doing so, ElringKlinger makes a sustainable contribution to climate-neutral European battery cell production.

2.1.5 Varta - Micro Production – IPCEI-Project

Company: VARTA AG produces and markets a comprehensive battery portfolio ranging from microbatteries, household batteries, and energy storage systems to customized battery solutions for a wide variety of applications.

As the parent company of the group, it operates in the business segments “Microbatteries & Solutions” and “Household Batteries.” The “Microbatteries & Solutions” segment focuses on the OEM business for microbatteries as well as the lithium-ion battery pack business. Through intensive research and development, VARTA, together with its subsidiaries VARTA Microbattery GmbH and VARTA Micro Production GmbH, sets global standards in the field of microbatteries and is a recognized innovation leader in the key growth markets of lithium-ion technology and primary hearing aid batteries.

The VARTA AG Group currently employs nearly 4,000 people. With five production and manufacturing sites in Europe and Asia, as well as sales centers in Asia, Europe, and the USA, VARTA AG’s operating subsidiaries are currently active in over 75 countries worldwide.

Company:	**IPCEI Workstreams:**
VARTA Micro Production GmbH Nürnberger Straße 65 86720 Nördlingen https://www.varta.com	• Cells & Modules

Project: Project: The project aims to research and develop novel lithium-ion cells, sustainable and efficient manufacturing processes, as well as the industrialization of the latest innovations in lithium-ion technology in Europe. It specifically seeks to close the gap between proof of concept in an ideal laboratory environment and complex mass production conditions.

Beyond technical and technological goals, solutions for largely climate-neutral cell production will be developed and implemented. A production line for lithium-ion cells in special formats for the consumer market will be established.

In the further course, capacities are to be scaled up and developed into globally competitive mass production.

2. Battery systems

2.2.1 BMW AG -IPCEI-Project

Company: The BMW Group, with its brands BMW, MINI, Rolls-Royce, and BMW Motorrad, is the world’s leading premium manufacturer of automobiles and motorcycles and a provider of premium financial and mobility services. The BMW Group’s production network comprises over 30 production sites worldwide, and the company has a global sales network with representatives in over 140 countries. In 2022, the BMW Group achieved global sales of nearly 2.4 million automobiles and over 202,000 motorcycles. The pre-tax profit for the 2022 fiscal year amounted to €23.5 billion, with revenues of €142.6 billion. As of December 31, 2022, the company employed 149,475 people worldwide. Long-term thinking and responsible action have always been the foundation of the BMW Group’s economic success. The company set the course for the future at an early stage, consistently placing sustainability and resource conservation at the center of its strategy, from the supply chain to production and the end of the product lifecycle.

Company:	**IPCEI Workstreams:**
BMW AG Petuelring 130 80809 Munich https://www.bmwgroup.com	• Battery Systems • Cells & Modules

Project: The goal of BMW's project within the framework of the "IPCEI on Batteries" is the design (including the definition of cell chemistry), development, prototyping, and testing of a new, highly innovative generation of lithium-ion cells. For this purpose, various prototype phases of sample cells will be built, tested, and analyzed.

The final target cell will then be produced on a pilot line and fully validated as part of the proof-of-concept review, serving as the basis for industrialization by a European cell manufacturer.

Another significant part of the project is the design of an innovative module and battery system aimed at substantially reducing production times, lowering costs, increasing energy density, and, in particular, significantly improving recyclability as a basis for reintegrating materials into the production process.

2.2.2 Skeleton Technologies GmbH – IPCEI-Project

Company: Skeleton Technologies is Europe's leading manufacturer of supercapacitors.

The innovative company was founded in Estonia in 2009 and has also been active in Germany since 2013. Since 2018, Skeleton Technologies GmbH has been producing supercapacitors for the global market at its plant in Saxony. Supercapacitors are high-performance energy storage devices that can be charged and discharged within fractions of a second and withstand over 1,000,000 charge-discharge cycles.

Skeleton Technologies aims to double the energy density of supercapacitors by utilizing its patented "Curved Graphene" technology.

Company:	**IPCEI Workstreams:**
Skeleton Technologies GmbH Schücostraße 8 01900 Großröhrsdorf https://www.skeletontech.com	• Battery Systems • Cells & Modules

Project: A sustainable European value chain for lithium-ion batteries requires the development of hybrid energy storage systems that combine the advantages of lithium-ion batteries (high energy density) with those of supercapacitors (high power density, long lifespan).

To reduce the costs of these systems, the costs of supercapacitors must be lowered, which requires significantly increased automation of supercapacitor production.

Within the framework of this project, Industry 4.0 solutions will be implemented for supercapacitor production to significantly reduce costs.

3. Re-use

2.3.1 BASF – Schwarzheide & Ludwigshafen – IPCEI-Project

Company: BASF creates chemistry for a sustainable future. More than 110,000 employees of the BASF Group work for the success of our customers in nearly all industries and in almost every country in the world. Our portfolio is divided into six segments with eleven business units.

The BASF Catalysts business unit is responsible not only for battery materials but also for our globally leading portfolio of environmental and process catalysts.

The BASF Process Research & Chemical Engineering technology platform develops new technologies and processes not only for battery research but for the entire range of chemical processes.

Company:	**IPCEI Workstreams:**
BASF SE Carl-Bosch-Straße 38 67056 Ludwigshafen am Rhein https://www.basf.com/global/de.html	• Reuse and Recycling • Raw Materials and Advanced Materials

Electromobility in Europe requires a locally integrated, cost-efficient battery value chain capable of delivering high-performance and sustainable batteries. BASF's new plant for producing cathode active materials (CAM) in Schwarzheide, Germany, is currently being gradually commissioned. There, cathode active materials of the latest and next generation are being manufactured using innovative production processes.
The project also includes intensive research activities for specific product properties and an efficient recycling technology. In addition, BASF is working on integrating a production facility for precursors (pCAM) in Harjavalta, Finland.

Further information at:

- http://catalysts.basf.com/groundbreaking
- https://catalysts.basf.com/products-and-industries/battery-materials

2.3.2 Liofit GmbH – IPCEI-Vorhaben

Company:	**IPCEI Workstreams:**
Liofit GmbH Nordstraße 57 01917 Kamenz https://www.liofit.com/	• Reuse and Recycling

Project: Liofit will apply the principle of the circular economy to lithium-ion batteries used in micro-mobility (pedelecs, e-scooters). These batteries will be inspected, disassembled, recombined, and repaired.
Batteries that can no longer be reused will be discharged in an environmentally friendly manner and shredded to enable the reuse of raw materials. Battery and recycling expertise will be combined under one roof, thus contributing to more climate-friendly mobility.

Milestones already achieved include a bicycle battery database with over 600 different types, inverter-based dischargers, and various strategies for module disassembly.

4. Materials

2.4.2 Umicore AG- IPCEI-Project

Company: Umicore is a materials technology company active in recycling, catalysis, and energy and surface technologies. The Umicore Group operates production facilities worldwide and serves a global customer base. In 2019, it generated revenues of €17.5 billion (€3.3 billion excluding precious metals) and employed around 11,150 people.

Building on a long-standing tradition in metallurgy and recycling, Umicore has developed and implemented the world's first industrial recycling process for Li-ion, Li-polymer, and NiMH batteries with high metal recovery rates.

Company: Umicore AG & Co. KG Rodenbacher Chaussee 4 63457 Hanau https://www.umicore.com	**IPCEI Workstreams:** • Raw Materials and Advanced Materials • Reuse and Recycling

Project: The goal of the project is to develop a safe and efficient reverse logistics concept for the collection, transport, and storage of large quantities of end-of-life (EoL) batteries from hybrid and fully electric vehicles (xEVs), as well as a highly efficient process for their disassembly as an important preliminary step for metallurgical recycling in a battery recycling technology center.

This contributes to building a sustainable and safe circular economy and securing the supply of technology metals for battery materials in Europe.

3 List of companies & institutions

COMPANY / INSTITUTION	PROJECT
ACATECH – DEUTSCHE AAKADEMIE DER TECHNIKWISSENSCHAFTEN	BatteryPass-Ready Batteriepass
ACCUREC-RECYCLING GESELLSCHAFT MBH	EarLi LIBERATION SUSTAIN
ACI SYSTEMS GMBH	ReAktiv
ACP SYSTEMS AG	MultiFlow ReAktiv
ADVANCED CAR TECHNOLOGY SYSTEMS GMBH & CO. KG	PEAk-Bat
ALFRED HERMANN GMBH & CO. KG	ULTRABATT
ALUMINA	IPCEI-Vorhaben
AMORPH SYSTEMS GMBH	ExElPro
ANSMANN AG	VaTreBat
AUDI AG	Batteriepass
AUTOMOTIVE CELL COMPANY ACC	IPCEI-Vorhaben
AUTOMOTIVE CLUSTER OSTDEUTSCHLAND GMBH	BatterieMD

AWZ GOTHA	BatterieMD
BASF	Batteriepass IPCEI-Vorhaben IPCEI-Vorhaben
BATTERIEINGENIEURE GMBH	LiPi METABatt
BAYERISCHE MOTOREN WERKE AKTIENGESELLSCHAFT, BMW AG	Batteriepass SimDural IPCEI-Vorhaben
BAYERISCHE GESELLSCHAFT FÜR INNOVATION UND WISSENSTRANSFER MBH , BAYERN INNOVATIV	B3-Bayern
BAYERISCHES ZENTRUM FÜR BATTERIETECHNIK (BAYBATT) AN DER UNIVERSITÄT BAYREUTH	B3-Bayern
BB&G ALTERNATIVE WORLDWIDE ENVIRONMENTAL SOLUTIONS LDA	KOLIBRI
BE-POWER GMBH	REVAMP
BERGISCHE UNIVERSITÄT WUPPERTAL, FAKULTÄT FÜR MASCHINENBAU UND SICHERHEITSTECHNIK	SUVEREN2Use
BERTRANDT TECHNIKUM GMBH	REVAMP
BERUFSFORTBILDUNGSWERK GEMEINNÜTZIGE BILDUNGSEINRICHTUNG DES DGB GMBH	BatterieMD KOMBiH
BILDUNGSWERK DER BADEN-WÜRTTEMBERGISCHEN WIRTSCHAFT E.V.	QualiBattBW
BILDUNGSWERK DER BAYERISCHEN WIRTSCHAFT (BBW) GGMBH	B3-Bayern

BRABENDER GMBH & CO. KG	TropMelt
BRANDENBURGISCHE TECHNISCHE UNIVERSITÄT COTTBUS-SENFTENBERG	KOMBiH
BST GMBH	ProMoBatt
CAPGEMINI ENGINEERING DEUTSCHLAND S.A.S. CO. KG	ExElPro
CARL ZEISS INDUSTRIELLE MESSTECHNIK GMBH	3DPrintBatt ProMoBatt
CELLFORCE GROUP	IPCEI-Vorhaben
CIRCULOR GMBH	Batteriepass
CIRCUNOMICS GMBH	COBALT-P
CLUSTER AUTOREGION E.V.	ABAKOS
CLUSTER ELEKTROMOBILITÄT SÜD-WEST C/O E-MOBIL BW – LANDESAGENTUR FÜR NEUE MOBILITÄTSLÖSUNGEN UND AUTOMOTIVE BADEN-WÜRTTEMBERG	QualiBattBW
CTG GMBH & CO. KG	LIBERATION
CUSTOMCELLS ITZEHOE GMBH	ExElPro ProMoBatt QuW-LIB
DAIMLER TRUCK AG	LiBinfinity Truckified Battery
DB-MATIK GMBH	3DPrintBatt

DEUTSCHES ZENTRUM FÜR LUFT- UND RAUMFAHRT E.V.	KOLIBRI
DIGATRON POWER ELECTRONICS	METABatt
DORST TECHNOLOGIES GMBH & CO. KG	ULTRABATT
DUALE HOCHSCHULE GERA-EISENACH	BatterieMD
EL-CELL GMBH	SimDural
ELFOLION GMBH	3D-Si-Elektrode
ELMUG ELEKTRONISCHE MESS- UND GERÄTETECHNIK THÜRINGEN EG	BatterieMD
ELRINGKLINGLER	IPCEI-Vorhaben
E-MOBIL BW GMBH	QualiBattBW
ENERGY SAXONY E. V.	BatterieMD
ENERGY WEB DEVHUB GMBH	COBALT-P
ERFURT BILDUNGSZENTRUM GGBMH	BatterieMD
ERNEUERBARE ENERGIEN HAMBURG CLUSTERAGENTUR GMBH EEHH	QuW-LIB
EVONIK OPERATIONS GMBH	EarLi

FERCHAU AUTOMOTIVE GMBH	SUSTAIN
FESTO LERNZENTRUM SAAR GMBH	ABAKOS
FIWARE FOUNDATION E.V.	Batteriepass
FOGTEC BRANDSCHUTZ GMBH	SUVEREN2Use
FORD-WERKE GMBH	ABAKOS PEAk-Bat
FRAUNHOFER-INSTITUT FÜR ARBEITSWIRTSCHAFT UND ORGANISATION IAO	QualiBattBW
FRAUNHOFER-INSTITUT FÜR BAUPHYSIK IBP	KOLIBRI
FRAUNHOFER-INSTITUT FÜR CHEMISCHE TECHNOLOGIE ICT	MultiFlow
FRAUNHOFER-INSTITUT FÜR DIGITALE MEDIENTECHNOLOGIE IDMT	E-LAS+
FRAUNHOFER-INSTITUT FÜR FERTIGUNGSTECHNIK UND ANGEWANDTE MATERIALFORSCHUNG IFAM	3DPrintBatt TropMelt
FRAUNHOFER-INSTITUT FÜR GIEßEREI-, COMPOSITE- UND VERARBEITUNGSTECHNIK IGCV	B3-Bayern
FRAUNHOFER-INSTITUT FÜR KERAMISCHE TECHNOLOGIEN UND SYSTEME IKTS	3DPrintBatt BatterieMD
FRAUNHOFER-INSTITUT FÜR NACHRICHTENTECHNIK – HEINRICH-HERTZ-INSTITUT	SUVEREN2Use
FRAUNHOFER-INSTITUT FÜR PRODUKTIONSTECHNIK UND AUTOMATISIERUNG IPA	ExElPro MultiFlow ReAktiv

	QualiBattBW ULTRABATT
FRAUNHOFER-INSTITUT FÜR PRODUKTIONSANLAGEN UND KONSTRUKTIONSTECHNIK IPK	3D-Si-Elektrode Batteriepass BatteryPass-Ready
FRAUENHOFER-INSTITUT FÜR PRODUKTIONSTECHNOLOGIE IPT	REVAMP
FRAUNHOFER-INSTITUT FÜR SILICATFORSCHUNG ISC	B3-Bayern HealthBatt
FRAUNHOFER-INSTITUT FÜR SOLARE ENERGIESYSTEME ISE	GRISU Longer MultiFlow Quaze ReAktiv SAMBA
FRAUNHOFER-INSTITUT FÜR SILIZIUMTECHNOLOGIE ISIT	QuW-LIB TropMelt
FRAUNHOFER-INSTITUT FÜR SCHICHT- UND OBERFLÄCHENTECHNIK IST	3DPrintBatt HVBatCycle
FRAUNHOFER-INSTITUT FÜR VERFAHRENSTECHNIK UND VERPACKUNG IVV	LIBERATION MultiFlow
FRAUNHOFER-EINRICHTUNG FÜR WERTSTOFFKREISLÄUFE UND RESSOURCENSTRATEGIE IWKS	ReAktiv
GEFEG	BatteryPass-Ready
HEINZE AKADEMIE GMBH	QuW-LIB
HOCHSCHULE AALEN	ProMoBatt SUSTAIN
HOCHSCHULE FÜR ANGEWANDTE WISSENSCHAFTEN HAMBURG	GRISU

HOCHSCHULE FÜR ANGEWANDTE WISSENSCHAFTEN LANDSHUT	B3-Bayern
HOCHSCHULE FÜR TECHNIK UND WIRTSCHAFT DES SAARLANDES	ABAKOS
HOCHSCHULE HEILBRONN	QualiBattBW
HORIBA EUROPE GMBH	3DPrintBatt
IBG AUTOMATION GMBH	REVAMP
INFINEON TECHNOLOGIES AG	HealthBatt
INSTITUT FÜR NANOTECHNOLOGIE UND MIKROSKOPIE GMBH INAM	3DPrintBatt
INTEGO GMBH	3DPrintBatt
J. SCHMALZ GMBH	HVBatCycle ProMoBatt VaTreBat
JONAS & REDMANN AUTOMATIONSTECHNIK GMBH	ProMoBatt
KARLSRUHER INSTITUT FÜR TECHNOLOGIE	LiBinfinity ProMoBatt QualiBattBW SimDural
KÖNIGSWARTER & EBELL CHEMISCHE FABRIK	NMC-Direct
K-UTEC AG SALT TECHNOLOGIES	ReAktiv
LANXESS DEUTSCHLAND GMBH	LiFe cycle

LEICA MICROSYSTEMS CMS GMBH	3DPrintBatt
LEISTER TECHNOLOGIES DEUTSCHLAND GMBH	MultiFlow
LIOFIT GMBH	IPCEI-Vorhaben
LOBBE ENTSORGUNG WEST GMBH & CO KG	SUVEREN2Use
M. BRAUN INERTGAS-SYSTEME GMBH	HOBAZELL
MAN TRUCK & BUS SE	REVAMP
MB AUTOMATION GMBH & CO. KG	HOBAZELL
MERCEDES-BENZ AG	LiBinfinity LiFe cycle
MESSRING GMBH	GRISU
MICROVAST GMBH	SAMBA
MIONTEC GMBH	Li-GeReKo
NEUROCONTROLS GMBH	E-LAS+
NOVUM ENGINEERING GMBH	Longer
OPTIMA LIFE SCIENCE GMBH	MultiFlow

ÖKO-INSTITUT E.V.	EarLi LIBERATION
POWERCO SE	HVBatCycle
PRECITEC GMBH & CO. KG	Quaze
PRECITEC OPTRONIK GMBH	Quaze
PRIMOBIUS GMBH	LiBinfinity
PVA TEPLA ANALYTICAL SYSTEMS GMBH	SAMBA
RCB NANOTECHNOLOGIES GMBH	KOLIBRI
REDUX RECYCLING GMBH	VaTreBat
RHEINISCHE HOCHSCHULE KÖLN GGMBH	SUSTAIN
RWTH AACHEN	B3-Bayern COBALT-P METABatt EarLi HVBatCycle PEAk-Bat REVAMP VALUE-M
SAFION GMBH	METABatt REVAMP
SCHWEIßTECHNISCHE LEHR- UND VERSUCHSANSTALT HALLE GMBH	BatterieMD

SCIO TECHNOLOGY GMBH	PEAk-Bat
SGS GERMANY GMBH	SimDural
SIEMENS AKTIENGESELLSCHAFT	VALUE-M
SIEMENS ENERGY GLOBAL GMBH & CO.KG	MultiFlow
SIEMENS INDUSTRY SOFTWARE GMBH	SimDural
SITEC INDUSTRIETECHNOLOGIE GMBH	E-LAS+ VaTreBat
SKELETON	IPCEI-Vorhaben
SKZ – KFE GGMBH	B3-Bayern
SMS GROUP GMBH	LiBinfinity
SOBEK MOTORSPORTTECHNIK GMBH & CO. KG	ULTRABATT
SOFTWARE AG	REVAMP
SSI SOFTWARE SERVICES GMBH	E-LAS+
SWW WUNSIEDEL GMBH	VALUE-M
SYSTEMIQ DEUTSCHLAND GMBH	Batteriepass

TANIOBIS GMBH	HVBatCycle
TECHNISCHE HOCHSCHULE INGOLSTADT	SUSTAIN
TECHNISCHE HOCHSCHULE KÖLN	Li-GeReKo
TECHNISCHE HOCHSCHULE ULM	QualiBattBW
TECHNISCHE HOCHSCHULE WÜRZBURG-SCHWEINFURT	B3-Bayern
TECHNISCHE UNIVERSITÄT BERGAKADEMI FREIBERG	3D-Si-Elektrode ReAktiv
TECHNISCHE UNIVERSITÄT BERLIN	BatteryPass-Ready KOMBiH LiBinfinity LiPi ProMoBatt
TECHNISCHE UNIVERSITÄT BRAUNSCHWEIG	3DPrintBatt HVBatCycle SimDural VaTreBat
TECHNISCHE UNIVERSITÄT CLAUSTHAL	LiBinfinity
TECHNISCHE UNIVERSITÄT MÜNCHEN	B3-Bayern HealthBatt
TES-AMM CENTRAL EUROPE GMBH	COBALT-P
TRUMPF SE + CO. KG	PEAk-Bat
TÜV RHEINLAND AUTOMOTIVE COMPONENT TESTING GMBH	PEAk-Bat

TWAICE TECHNOLOGIES	Batteriepass
TWT GMBH SCIENCE & INNOVATION	Longer
UMICORE AG	Batteriepass IPCEI-Vorhaben
UNIVERCELL HOLDING GMBH	KOLIBRI TropMelt
UNIVERSITÄT DES SAARLANDES	ABAKOS
UNIVERSITÄT ERFURT	BatterieMD
UNIVERSITÄT STUTTGART	QualiBattBW ReAktiv ULTRABATT
VARTA	IPCEI-Vorhaben
VARTA MICROBATTERY GMBH	3D-Si-Elektrode 3DPrintBatt
VARTA STORAGE GMBH	HealthBatt Longer
VEREINIGUNG FÜR BETRIEBLICHE BILDUNGSFORSCHUNG E. V.	KOMBiH
VHS-BILDUNGSWERK GMBH	BatterieMD
VOLTAVISION GMBH	SUSTAIN
VRI GMBH BATTERIE TECHNIK	E-LAS+

VULCAN GMBH	ZeroCaLi
WACKER NEUSON PRODUKTION GMBH & CO. KG	REVAMP
WEIDEMANN GMBH	REVAMP
WESTFÄLISCHE WILHELMS-UNIVERSITÄT MÜNSTER MEET	NMC-Direct
WHITECELL EISENHUTH GMBH & CO. KG	MultiFlow
WOLL MASCHINENBAU GMBH	ABAKOS
ZENTRUM FÜR SONNENENERGIE- UND WASSERSTOFF-FORSCHUNG BADEN-WÜRTTEMBERG ZSW	HOBAZELL QualiBattBW
ZEPPELIN SYSTEMS GMBH	KOLIBRI