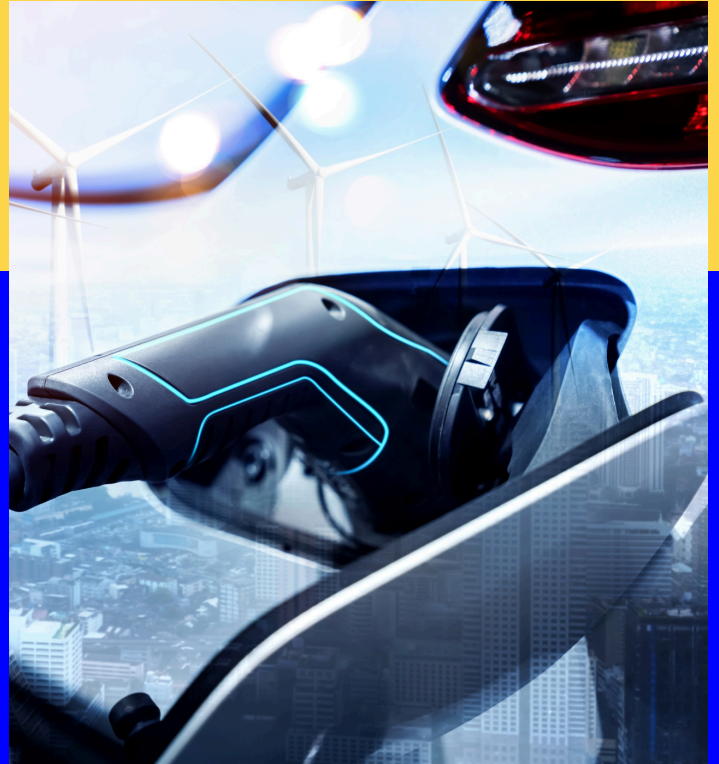
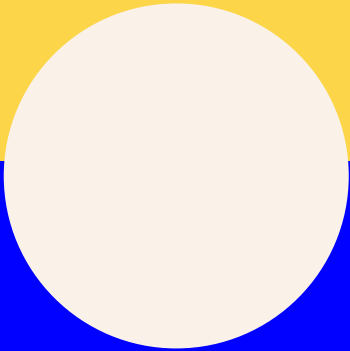
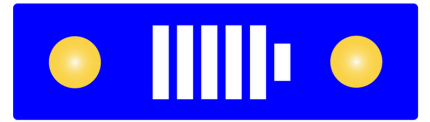


**SPINMATE**

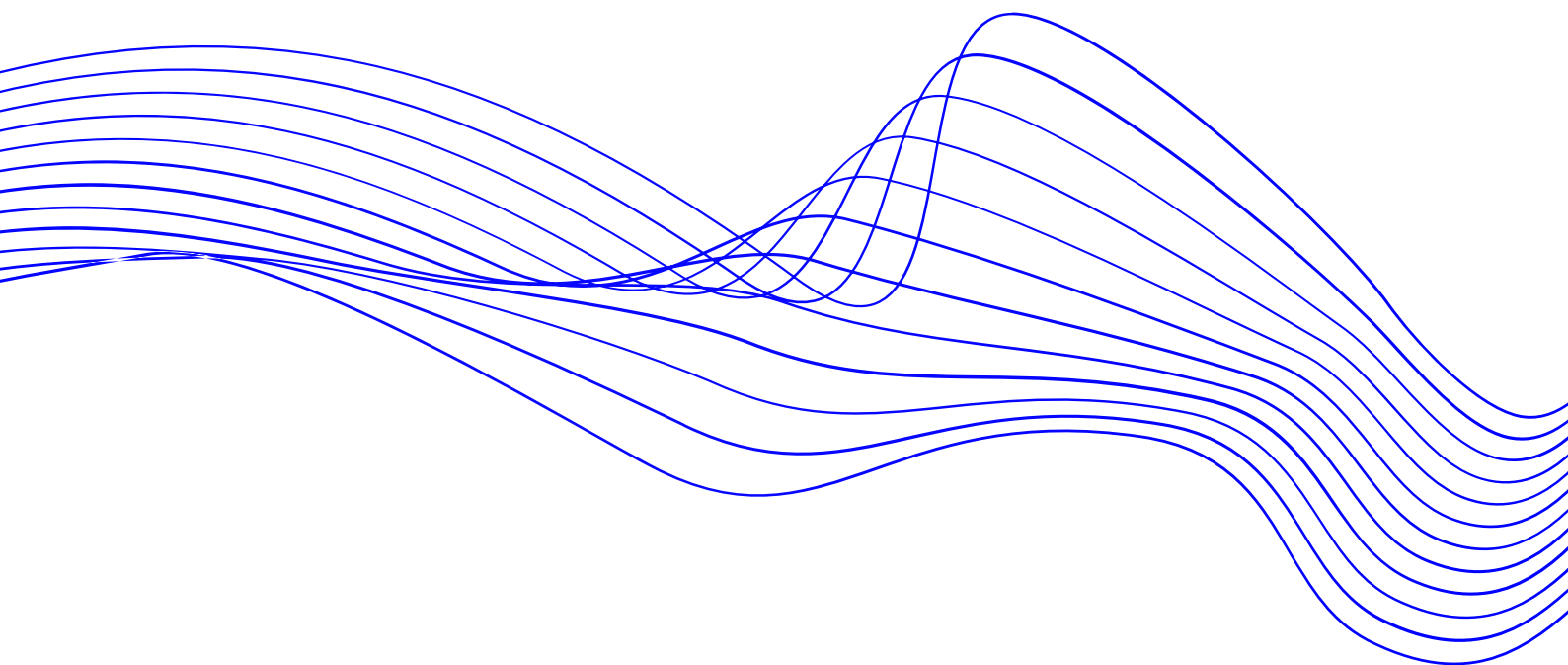


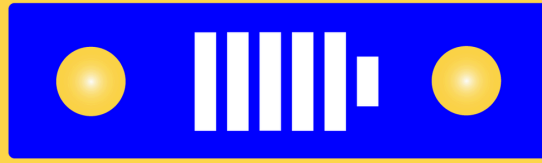
# **PROJECT BOOKLET**



**SPINMATE**

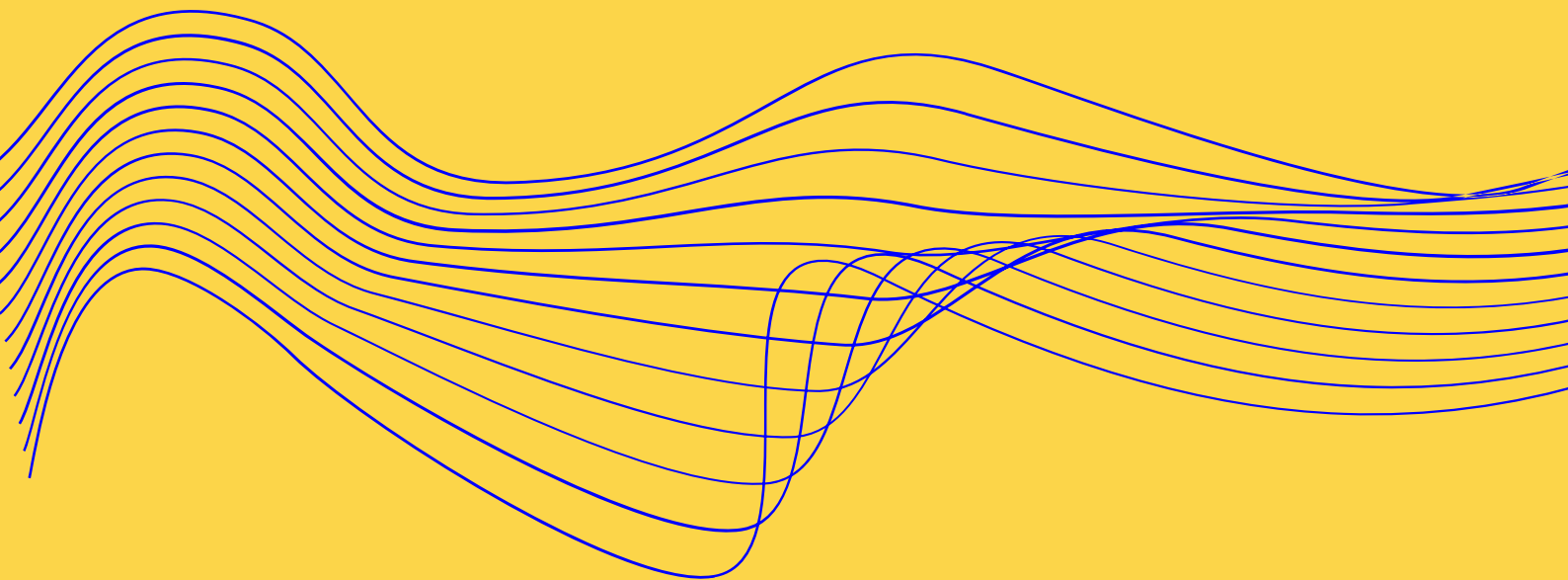
**ONE STEP  
FORWARD TO  
GREENER  
AND CLEANER  
ENERGY.**





# SPINMATE

Scalable and Sustainable Pilot Line based on innovative manufacturing technologies towards the industrialisation of Solid-State Batteries for the automotive sector



Cross-sectoral solutions for the  
climate transition:  
Manufacturing technology  
development for solid-state batteries

**Horizon Europe Framework Programme**

◆◆◆◆ **PROJECT COORDINATOR**  
AVESTA BATTERY & ENERGY ENGINEERING

◆◆◆◆ **PROJECT BUDGET**  
€ 6 976 599,50

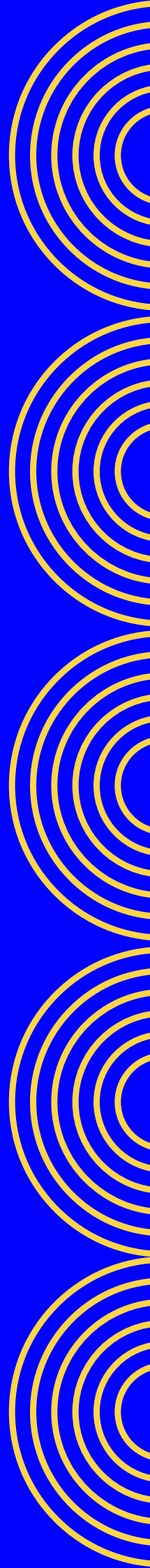
◆◆◆◆ **EU CONTRIBUTION**  
€ 6 976 599,50

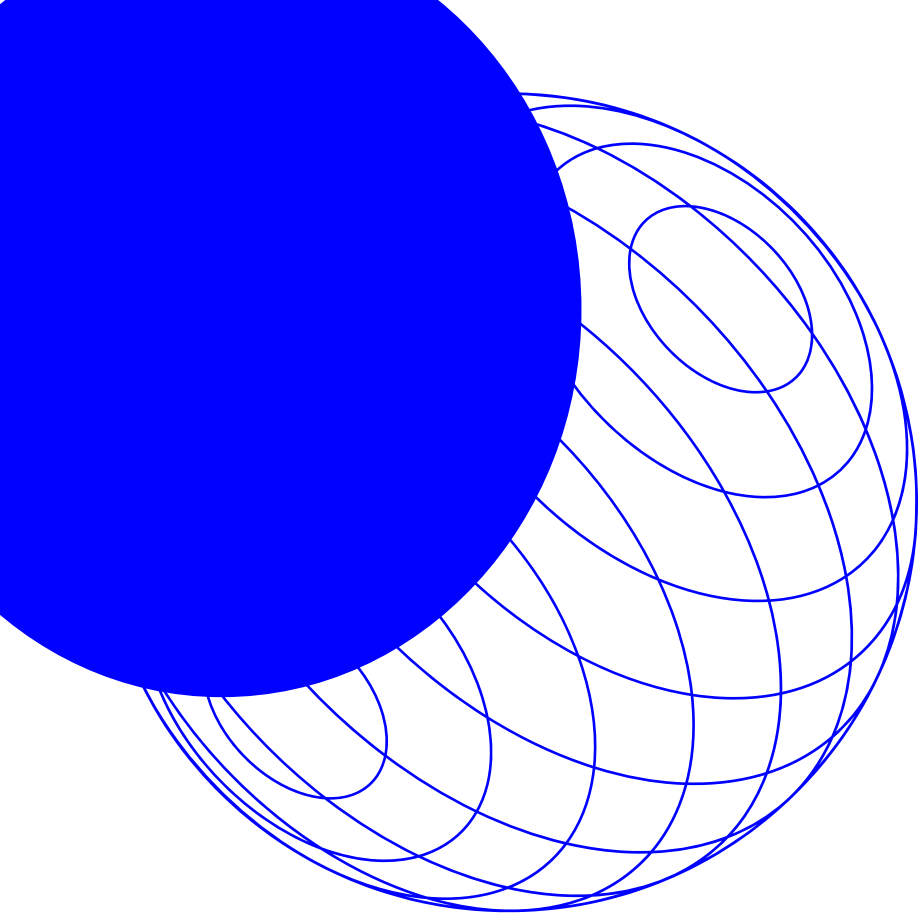
◆◆◆◆ **PROJECT DURATION**  
48 MONTHS: AUGUST 2022 – JULY 2026

◆◆◆◆ **CALL**  
HORIZON-CL5-2021-D2-01

◆◆◆◆ **DESTINATION**  
CROSS-SECTORAL SOLUTIONS FOR THE CLIMATE  
TRANSITION

◆◆◆◆ **TOPIC**  
MANUFACTURING TECHNOLOGY DEVELOPMENT FOR  
SOLID-STATE BATTERIES





**AVESTA**



**TOYOTA**

CIC  
**energi**  
GUNE



**ARKEMA**



**INOVA+**

**MEET THE  
CONSORTIUM**

# 01 AVESTA

## EXPERTISE

Avesta Battery & Energy Engineering [ABEE] specializes in advanced Li-ion and solid-state battery technology, covering battery system design, manufacturing, and recycling. They develop multi-scale simulation tools and set up cutting-edge battery manufacturing infrastructures.

## ROLE IN SPINMATE

As Project Coordinator, ABEE leads the development of the pilot production line, manages key work packages on project coordination and equipment development, and focuses on recycling process optimization to enhance sustainability and efficiency.

---

# 02 Fraunhofer ISC

## EXPERTISE

Fraunhofer Gesellschaft zur Foerderung der Angewandten Forschung e.V. [ISCF], through its Fraunhofer R&D Center for Electromobility Bavaria, specializes in battery materials, process development, and upscaling solid-state battery technologies from laboratory to pilot scale. They are experts in developing next-generation battery components and optimizing battery performance.

## ROLE IN SPINMATE

ISCF focuses on the development and optimization of cell components, particularly lithium metal surfaces, using innovative techniques like sandblasting. They are also responsible for assessing the performance and aging of solid-state batteries, contributing to process development and prototype validation.

---

# 03 COMAU

## EXPERTISE

Comau Spa [COMAU] is a global leader in industrial automation, providing advanced solutions for manufacturing, robotics, and digital services. With over 50 years of experience, Comau develops cutting-edge technologies for battery cell production and offers automated solutions for electric and hybrid vehicle manufacturing.

## ROLE IN SPINMATE

Comau oversees the digitalization and automation of battery manufacturing in SPINMATE. They develop digital models for production, optimize equipment for solid-state battery assembly, and ensure industrial feasibility. Comau also defines pilot line requirements and integrates real-time process adjustments using digital tools.

---





#### EXPERTISE

Technische Universität Braunschweig [TUBS], through its Institute for Particle Technology [iPAT], focuses on advancing battery process engineering in the SPINMATE project. They specialize in particle technology and polymer-based solid-state batteries (SSBs), with expertise in PEO-based electrolytes.

#### ROLE IN SPINMATE

TUBS leads the design of 1 Ah and 10 Ah SSB prototypes, optimizing production through their expertise in comminution, coating, and nanomaterials. They use solvent-based and dry coating methods to scale production and monitor quality by tracking parameters like electrode thickness, mass loading, and electrochemical performance.

## 05 TOYOTA

#### EXPERTISE

Toyota Motor Europe NV [TME] brings its battery technology expertise to SPINMATE, leading the work package on “Specification Requirements and Standardization.” TME defines key performance indicators and testing protocols to align battery production with electric vehicle standards.

#### ROLE IN SPINMATE

Toyota focuses on energy density, lightweight materials, and optimized pilot line parameters helps develop scalable solid-state batteries for automotive industry needs.

06



#### EXPERTISE

Commissariat à l'Énergie Atomique et aux Énergies Alternatives [CEA] leads testing and validation of solid-state battery (SSB) performance, aging, and safety in the SPINMATE project. They specialize in advanced energy technologies, including lithium-ion and post-lithium-ion batteries.

#### ROLE IN SPINMATE

In SPINMATE, CEA tests battery cells for automotive use, ensuring they meet safety and durability standards while assessing environmental impacts through life cycle analysis and recycling studies.



#### EXPERTISE

Fundación CIDETEC [CID] contributes to SPINMATE with expertise in advanced battery technology, focusing on lithium metal solid-state batteries.

#### ROLE IN SPINMATE

CIDETEC develops positive electrodes for enhancing SSB performance and reproducibility, leading catholyte optimisation and upscaling lab processes for pilot plant production. They conduct electrochemical tests to ensure durability, safety, and compliance with EV industry standards.

---



#### EXPERTISE

CIC energiGUNE [CICe] is a leading energy research center specializing in electrochemical energy storage, focusing on advanced materials for battery technologies, including the development of polymer electrolytes and other materials for electrochemical applications.

#### ROLE IN SPINMATE

CIC energiGUNE optimizes cell components, focusing on the cathode, anode, and solid-state electrolyte, integrating them into monolayer cells. They refine composition and processing to enhance performance, testing for improved durability and energy density, advancing scalable solid-state battery technology for industry.

---



#### EXPERTISE

Arkema France SA [Arkema] is a leader in Specialty Materials, specializing in innovative and sustainable solutions across various industries. Leveraging its expertise in materials science, Arkema addresses the needs of new energy technologies, mobility, and resource challenges.

#### ROLE IN SPINMATE

Arkema will develop and scale-up a high-conductivity, thermally stable solid electrolyte for use as a membrane separator and catholyte in the battery system, utilizing its proprietary polymer and lithium salt.

---



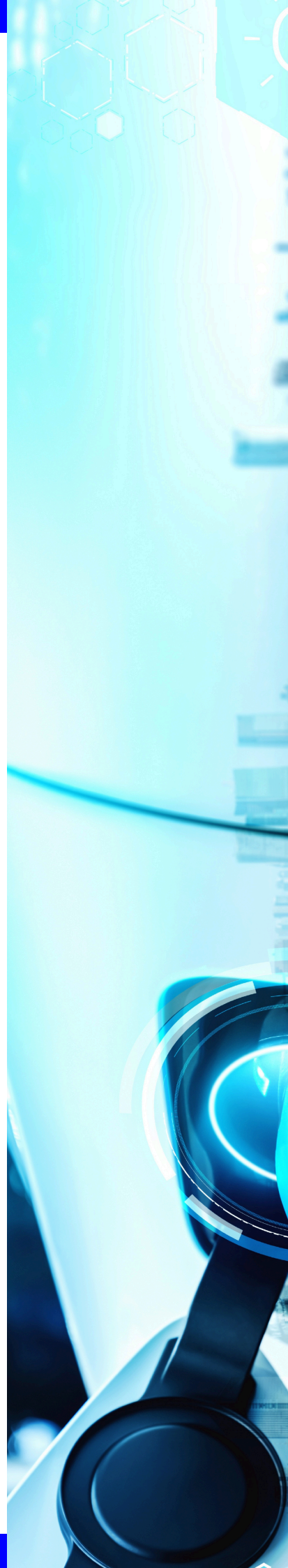
#### EXPERTISE

Institute of Science and Innovation in Mechanical and Industrial Engineering [INEGI], specializing in technology-based innovation, technology transfer, consulting, and advanced engineering services, focuses on developing new technologies for advanced production processes, sustainability, mechanics, and product development.

#### ROLE IN SPINMATE

Leading the environmental and cost impact assessments throughout the value chain. The organization uses its expertise in sustainability to evaluate the lifecycle of the SSB pilot line, ensuring it is environmentally friendly and cost-effective.

---







### EXPERTISE

Fundació Institut de Recerca de L'Energia de Catalunya [IREC] specializes in sustainable energy solutions, focusing on material synthesis, physicochemical characterization, performance optimization, and electrode formulation, fabrication, and testing. Their research spans electrochemical energy storage technologies, specifically advancing battery components like Ni-rich layered oxide cathodes.

### ROLE IN SPINMATE

In SPINMATE, IREC leads the optimization and benchmarking of Ni-rich layered oxide cathode materials, working with partners to develop high-capacity active materials suited for solid-state batteries. They manage the physicochemical and electrochemical characterization of cathodes, support monolayer cell testing to improve energy density and cycle life, and conduct degradation analysis using techniques like impedance spectroscopy to identify performance-limiting factors.



### EXPERTISE

Ceramic Powder Technology AS [CPT] specializes in advanced ceramic oxide powder production using spray pyrolysis to achieve high-purity, homogeneous sub-micron powders suitable for a range of industrial applications.

### ROLE IN SPINMATE

In SPINMATE, Cerpotech leads the upscaling of high-capacity Ni-rich layered oxide cathode materials, optimizing powder morphology to ensure compatibility with cathode manufacturing processes. They are responsible for refining production techniques to achieve the necessary crystallinity and reduce agglomeration, supporting large-cell manufacturing for solid-state batteries.



### EXPERTISE

INOVA+ Innovation Services, S.A. [INOVA] specializes in driving organizational growth through innovation, international cooperation, digital transformation, and access to funding. With offices in Porto, Brussels, Heidelberg, Warsaw, and Lisbon, the company focuses on enhancing global collaboration.

### ROLE IN SPINMATE

INOVA+ brings over 25 years of experience in international projects, acting as a technology broker. It leads the design and implementation of the Communication, Dissemination, and Exploitation strategy for SPINMATE, coordinating efforts across all partners.

# ABOUT SPINMATE

The SPINMATE project aims to demonstrate a digitally driven proof-of-concept pilot line that is scalable, sustainable, safe, and cost effective as a first step toward the large-scale production of generation 4b solid state battery (Gen 4b SSB) cells and modules to support the electrification of the automotive industry.

To reach this goal, SPINMATE proposes the development and implementation of innovative and scalable manufacturing and processing solutions (notching/cutting, stacking and sealing/packaging steps, among others).

Novel industry 4.0 and 5.0 concepts (Industrial Internet of Things – IIoT and Machine Learning – Machine Learning algorithms, Digital Twins, giga-factory line simulation,...) are proposed to be applied for the digitalisation of the proof-of-concept pilot line, as well as the assembly and manufacturing processes.

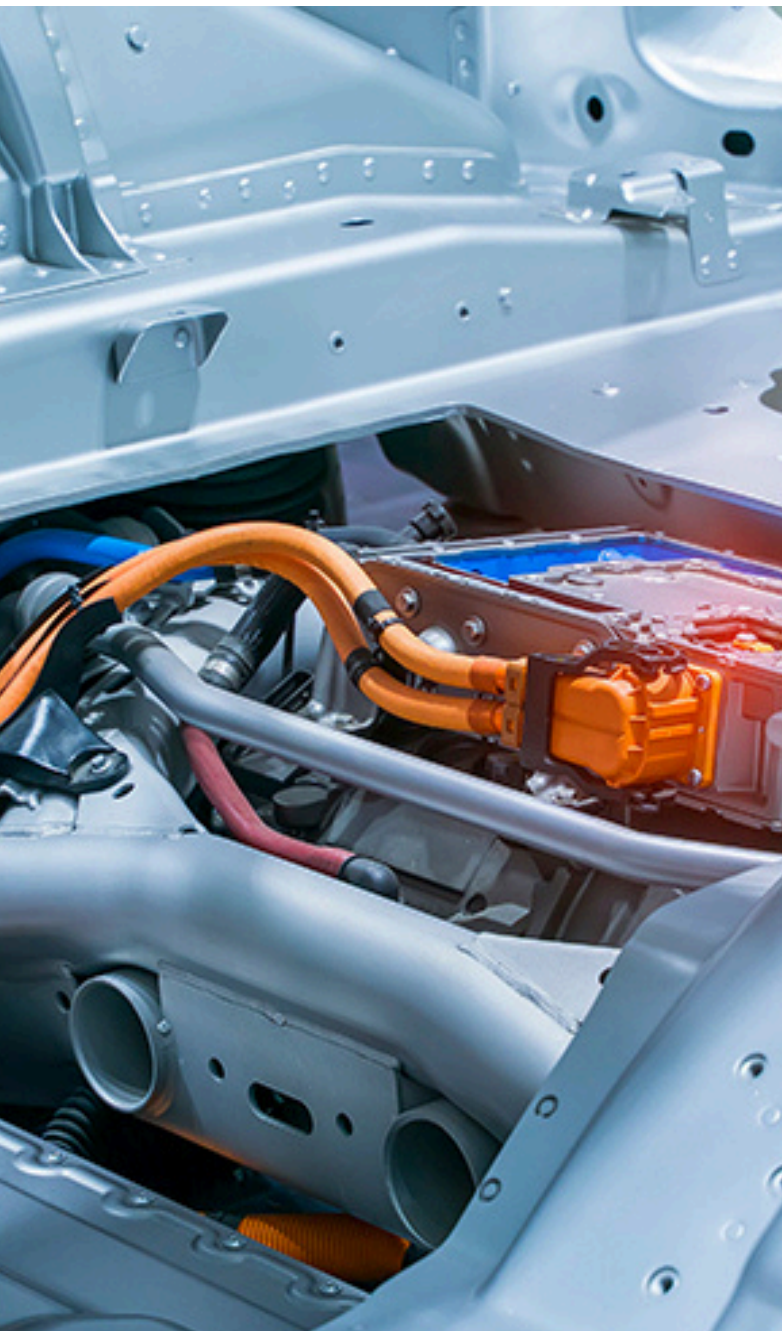
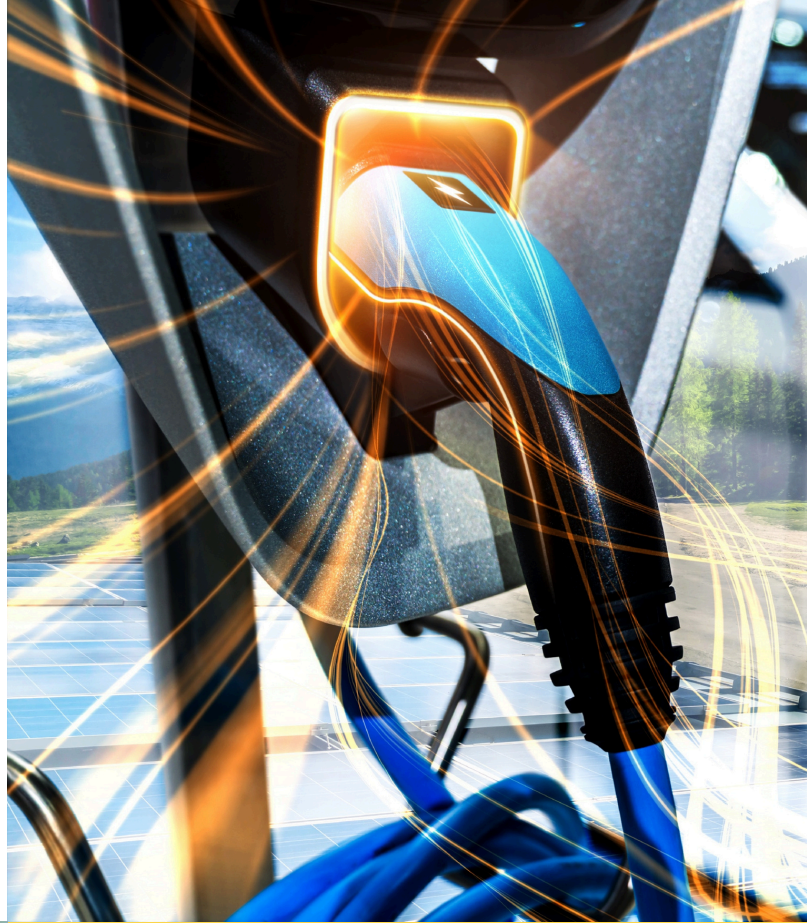
The key focus areas of SPINMATE are:



# OUR MISSION

The SPINMATE's Gen 4b SSB cells will create a new industry value chain in Europe towards their commercialization. This new generation technology will ensure:

- Enhance energy densities, overcoming current Li-ion batteries limitations
- Improved safety in both solutions and workers
- Increased sustainable mass production
- Decreased carbon footprint and cost



SPINMATE project will commit the challenge of reaching the first milestone towards the large-scale manufacturing of generation 4b (Gen 4b) SSB cells, while demonstrating the cost-effective digital-driven proof-of-concept pilot line at a TRL6 level, that will comprise industry 4.0 and 5.0 digital manufacturing concepts.

By means of different digitalisation approaches, SPINMATE processing and manufacturing innovations will contribute for:



A sustainable and competitive large-scale production of SSBs (i.e., based on market-oriented roadmap)



The reduction of the carbon footprint



Enhancement of safety along the entire value chain

# OUR CHALLENGE

# OUR OBJECTIVES

## 01

---

**Identify and define specifications and standards** required to manufacture Gen 4b SSB cells (in particular for the EV sector), and to develop an innovative and sustainable pilot line.

## 02

---

**Develop, optimize and produce** new solid electrolytes at large scale to be combined with Li metal-based anodes and high Nickel content oxides as cathodes, leading to enhanced energy densities.

## 03

---

**Create and employ digital solutions** to optimise the SPINMATE manufacturing processes, focusing on the safety, performance, sustainability, and production costs, and to contribute to the positioning of Europe as leader in the industrial production of Gen 4b SSB technologies by addressing the whole value chain.

## 04

---

**Develop indigenous and new technologies** and improve manufacturing processes to assemble an innovative digital-driven pilot line towards the production of Gen 4b SSB cells, as well as their components, while increasing mass production costs and reducing environmental impacts.

## 05

---

**Design, manufacture and validate Gen4b SSB cell prototypes**, combining advanced materials and chemistries, while demonstrating the fulfilment of the EV sector's requirements and standards, and achieving the KPIs directly linked with the technological competitiveness of the Gen 4b technology in a cost-efficient and sustainable way.

## 06

---

**Create and establish a wide knowledge portfolio**, engaging the key stakeholders and end users to expand the project's scope towards new market opportunities to maximise its impact.

1

## **Support Europe to lead SSB production**

---

Position Europe at the industrial production lead on SSBs through new business models and patents/utility models registration.

# **SPINMATE'S OUTCOMES**

2

## **Mass Production of SSB Cells**

---

Provide cost effective, low carbon footprint, low-emission mass production with higher safety of gen4 technology, fostering the mass-scale production of SSB cells in Europe.

3

## **Enhance know-how on SSB manufacturing**

---

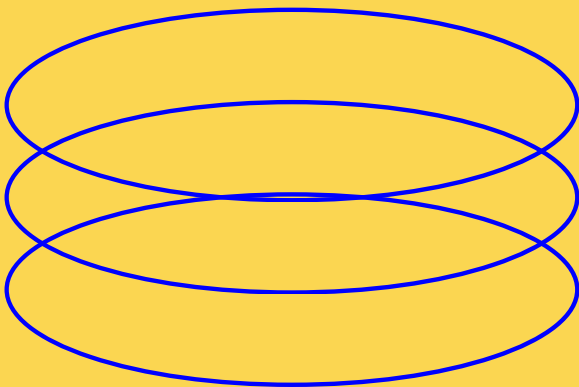
Upskill researchers and industrialists, leading to new high-skilled full-time jobs in mid-term and new multidisciplinary positions in long-term.

4

## **Influence Battery Policy and Decision-Making**

---

Contribute to the batteries policy and decision-making processes, tackling of specific EU policy priorities in 4 regulatory fields: EV, safety, recycling and electrochemical performance, and durability.



# WORK PLAN

The SPINMATE project is organized into 9 interconnected Work Packages (WPs), each contributing to the overall goal of developing scalable, innovative solid-state battery (SSB) solutions for the EV industry.

## **WP1: Project Coordination and Management [Leader: ABEE]**

Ensures the strategic coordination and efficient management of the project, overseeing progress, controlling timelines, and regularly updating the European Commission.

## **WP2: Definition of Performance Standards [Leader: TME]**

Focuses on establishing Key Performance Indicators (KPIs) and industry standards that the Gen 4b SSB cells must meet. This will ensure the final products align with the technical and safety requirements of the EV industry.

## **WP3: Optimization of Battery Cell Components [Leader: CICE]**

Optimises the core constituents of the SSB cells, including the electrolyte and electrode materials, will be optimized. The aim is to define a robust and efficient final cell chemistry to enhance battery performance.

## **WP4: Digitalization and Industrial Modeling [Leader: COMAU]**

Develops digital tools and modelling approaches to optimize the pilot line. This includes integrating smart manufacturing technologies to enhance efficiency and streamline the production process.





#### **WP5: Pilot Line Assembly and Equipment Optimization [Leader: ABEE]**

Builds on the results of previous WPs, WP5 focuses on developing and optimizing the necessary equipment for the assembly of the pilot line, laying the groundwork for scalable production.

#### **WP6: Manufacturing of SSB Cells [Leader: TUBS]**

Produces the 1 Ah and 10 Ah Gen 4b SSB cells using the pilot line. This phase involves the practical implementation of the optimized processes to manufacture high-quality battery cells.

#### **WP7: Testing and Validation [Leader: CEA]**

Assesses the performance of the manufactured solid-state battery (SSB) cells through rigorous testing and validation, ensuring they meet defined KPIs. This work package also evaluates the safety and reliability of both the cells and the pilot production line.

#### **WP8: Sustainability and Cost Analysis [Leader: INEGI]**

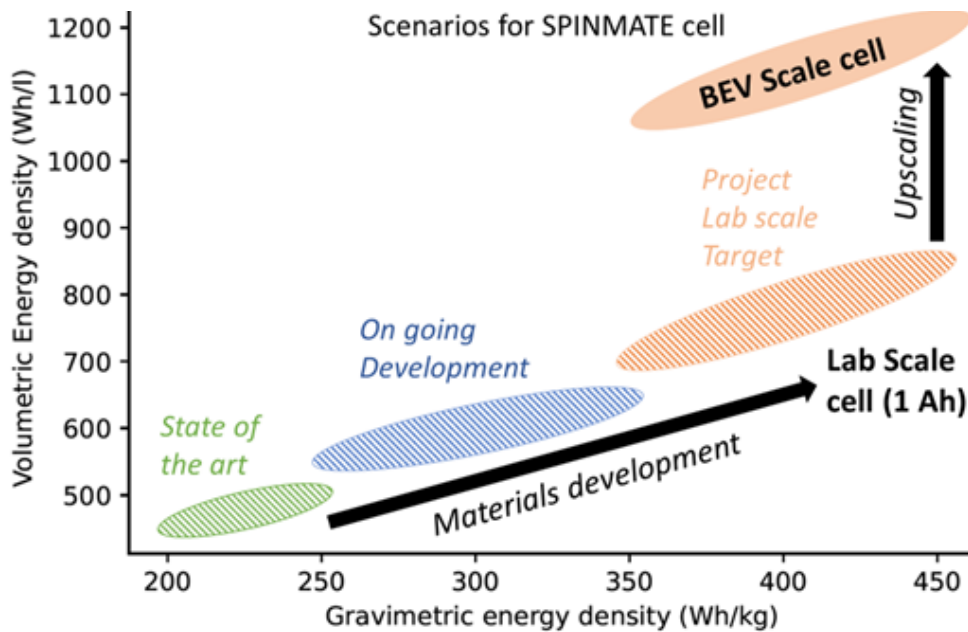
Evaluates the environmental and economic impact of the entire value chain. It aims to ensure that the developed solutions are both sustainable and cost-effective, contributing to a greener battery industry.

#### **WP9: Communication, Dissemination, and Exploitation [Leader: INOVA+]**

Maximises the visibility and impact of the SPINMATE project through comprehensive communication and dissemination activities. As a transversal work package, it ensures that project outcomes are effectively shared with stakeholders and target audiences, laying the groundwork for future exploitation of its innovations.

## Battery Cell Scenarios

SPINMATE partners, guided by TME, defined various scenarios to achieve ambitious energy density targets of 1200 Wh/L and 450 Wh/kg. These scenarios range from state-of-the-art to project-specific targets, optimizing cell components like polymer electrolyte thickness and cathode material capacity.



## Advanced Mathematical Modelling

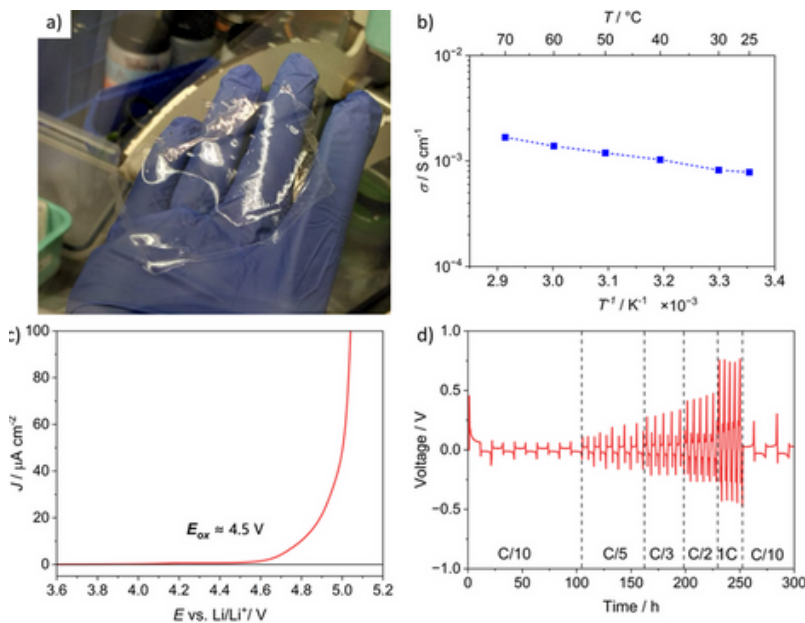
COMAU, in collaboration with project partners, is developing mathematical models for each process step of cell manufacturing. Data from experiments are collected and analyzed to identify key process parameters, supporting predictive modeling for quality and process optimization.

## Solid-State Cell Assembly

COMAU and ABEE are collaborating in the development of proper processes and tools for the assembly of solid-state cells based on Li-metal anode. The focus is mainly on electrode cutting and stacking: the innovative Li-metal anode and gel-polymer electrolyte present mechanical properties different from the conventional materials and thus require specific solutions for proper handling in automatic cell assembly, to avoid damages. The tools and solutions are developed paying particular attention to scalability and easy maintenance.



## Components for solid-state batteries



- a) Image of a GPE membrane developed in SPINMATE project;
- b) ionic conductivity as a function of the inverse of the temperature;
- c) oxidative stability of SPINAMTE GPE membranes;
- d) plating/stripping in Li||Li symmetric cells at room temperature and with a fixed capacity of 2 mAh/cm<sup>2</sup>, at various C-rates.

SPINMATE partners are developing solid-state battery components. CIC energiGUNE, ARKEMA, and CIDETEC created PVDF-based gel polymer electrolytes (GPEs) with high conductivity ( $\sim 1 \text{ mS/cm}$ ), stability ( $\sim 4.5 \text{ V}$ ), and dendrite resistance, showing promising room-temperature performance in full cells with high-voltage cathodes.

## Polymer Electrolyte Membranes

CIC energiGUNE, in partnership with ARKEMA and CIDETEC, has developed high-performance PVDF-based gel polymer electrolytes (GPEs). These electrolytes exhibit ionic conductivity of up to 1 mS/cm, excellent electrochemical stability (4.5 V), and resistance against lithium dendrite formation, ensuring reliable room-temperature operation.

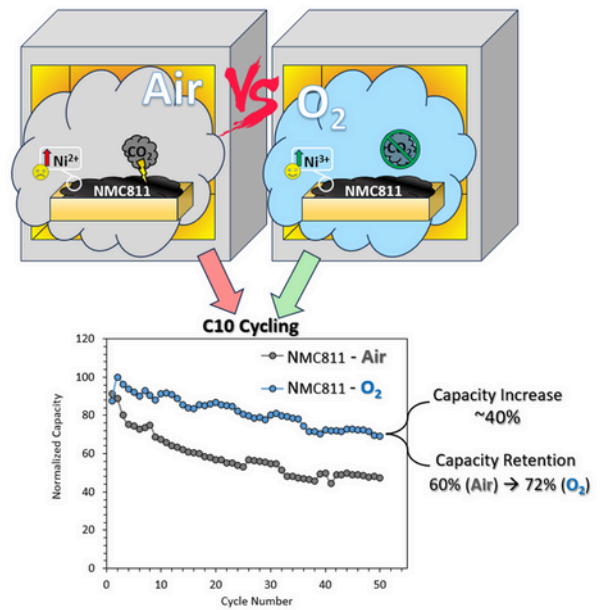
## Optimisation and Development of Positive Electrode

In the first phase of SPINMATE, CIDETEC optimized an NMC811-based positive electrode containing a catholyte developed with CIC energiGUNE and ARKEMA. The cathode was validated in coin cells to ensure performance and reproducibility. In the second phase, the formulation was scaled up at CIDETEC's pilot plant, producing  $\sim 26$  meters of solid-state cathode. This electrode was successfully tested in single-layer pouch cells, showing strong discharge capacity and efficiency at room temperature.

TECHNICAL  
ADVANCEMENTS

## Upgrading NMC811 material

As part of the SPINMATE project, IREC improved the performance of the NMC811 cathode material by optimizing the calcination process. By using an oxygen-rich atmosphere, they reduced surface carbonates and minimized cation mixing, both of which can negatively impact electrochemical properties. These adjustments led to a 40% increase in capacity and improved capacity retention from 60% to 72% over 50 cycles, demonstrating the importance of refining production processes for better material performance.



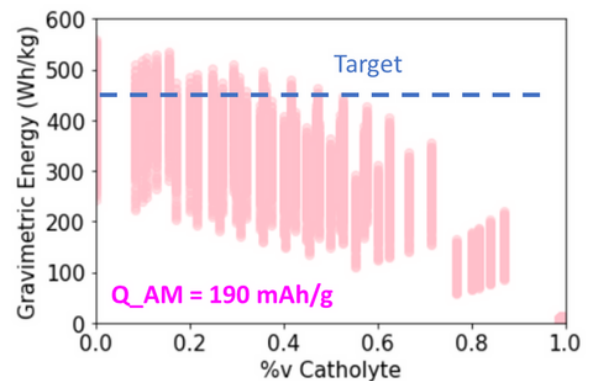
Influence of the calcination atmosphere on NMC811 cycle capacity

## Machine Learning and Data Analysis

COMAU, with support from SPINMATE partners, is leading data collection for electrode preparation and electrolyte membrane production. Next, they will gather data on cell assembly and formation. A detailed data list for the entire manufacturing process was shared with partners, and an experimental plan using a Design of Experiments (DoE) approach was developed to streamline data collection.

## Cell Targets

SPINMATE established key specifications to meet its targets effectively. Using dynamic Python modelling, key parameters like energy density were calculated, revealing the need for a positive electrode with a minimum thickness of 100  $\mu\text{m}$  and an active material capacity of 190 mAh/g to achieve 450 Wh/kg.

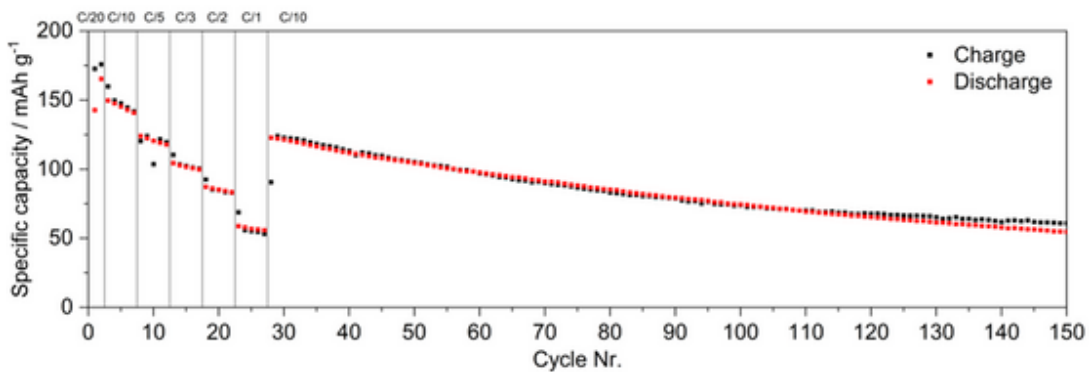


Gravimetric energy calculation obtained according to volumic percentage of electrolyte (catholyte) used in positive electrode.

A higher electrode loading and density were also identified as necessary, posing challenges for electrode processing and electrolyte performance.

## Components for solid-state batteries

Solid polymer electrolytes (SPEs) with high ionic conductivity (1 mS/cm), stability (4.5 V), and resistance to dendrite growth were created by CIC energiGUNE and ARKEMA. These SPEs were tested in coin cells with lithium anodes from ABEE and solid-state cathodes by CIDETEC and CERPOTECH, showing promising capacities of up to 160 mAh/g. The optimized SPEs are now being scaled up for the production of 50 single-layer pouch cells.



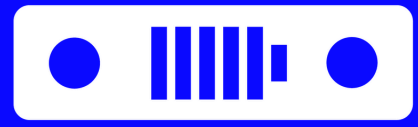
Full cell cycling

## Adjustments and Workshop Activities

From late 2023 to early 2024, ABEE and COMAU collaborated on optimizing equipment and processes for the SPINMATE project. A workshop held during the General Assembly in 2024 focused on improvements and future development strategies. The outcomes will support advancements in SPINMATE and other battery-related initiatives.

## Process Modelling

COMAU has initiated Machine Learning algorithms to model electrode preparation, using data collected during the project. Reusable data processing tools have been created, and ML models have been benchmarked to identify the best options for further development.



**SPINMATE**

**SPINMATE's training pills are specific communication and dissemination actions, carried out in the "Project Communication, Dissemination and Exploitation" work package to attract the interest of key industrial stakeholders and end users of the battery, EVs and related sectors. Therefore, this training activity aims to facilitate the acquisition of skills by industrialists and research infrastructures for exploiting the project results beyond the boundaries of the consortium.**

**During SPINMATE life cycle 3 training pills targeting the workers of the battery industry and research infrastructures will be developed for reskilling and upskilling them in the new SPINMATE solutions.**

**The first Training Pill can be found on SPINMATE's YouTube and it is structured by six topics and respective targets**

# **TRAINING PILLS**



# FIRST TRAINING PILL MODULES

*Knowledge sharing of SPINMATE insights and best practices to the community on*

## ***General Aspects***

Lowering carbon emissions and improving safety across the battery value chain to ensure sustainability and competitiveness.

## ***Manufacturing of cell components***

Targeting better performance, stability, and cost by enhancing polymer electrolyte conductivity and oxidative stability.

## ***Testing Batteries***

Testing battery performance under various conditions and ensuring safety with abusive tests like thermal runaway.

## ***Battery Materials***

Enabling flexible production of mixed oxide materials with high sinterability, aiding solid-state battery development.

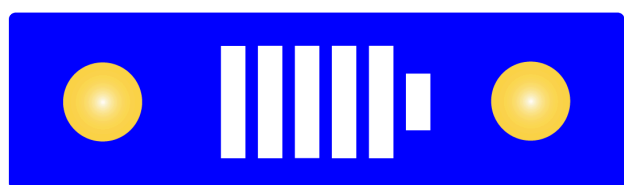
## ***Production Tools***

Improving lithium anode morphology and reducing thickness, while PVD methods enhance control and scalability.

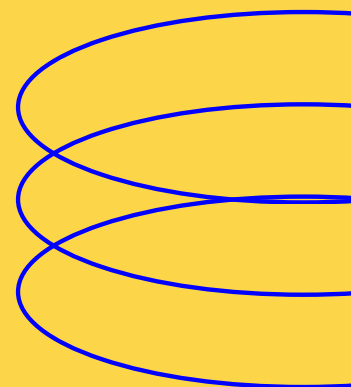
## ***The future of technology***

Assessing environmental impact and optimising processes for long-range, fast-charging, and affordable electric vehicle batteries.

## CONTACTS



# SPINMATE



Funded by  
the European Union

Funded by the European Union's Horizon Europe research and innovation program under grant agreement no. 101069712. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.