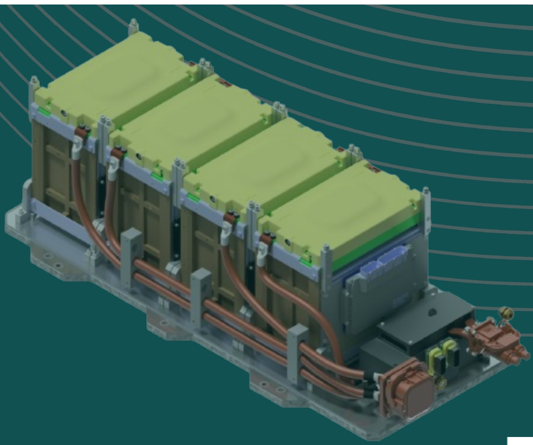
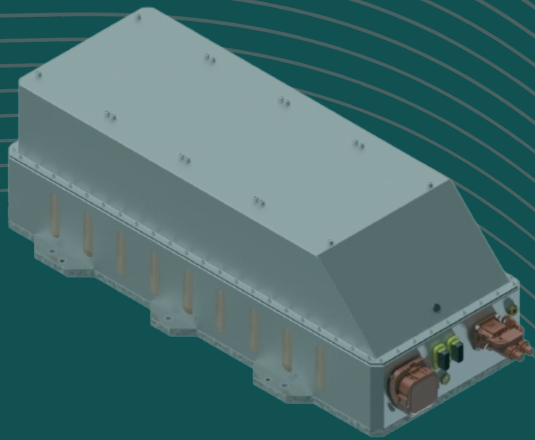
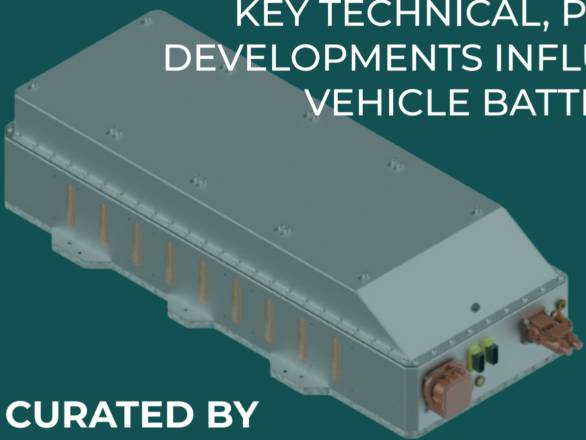
MARKET INTELLIGENCE REPORT

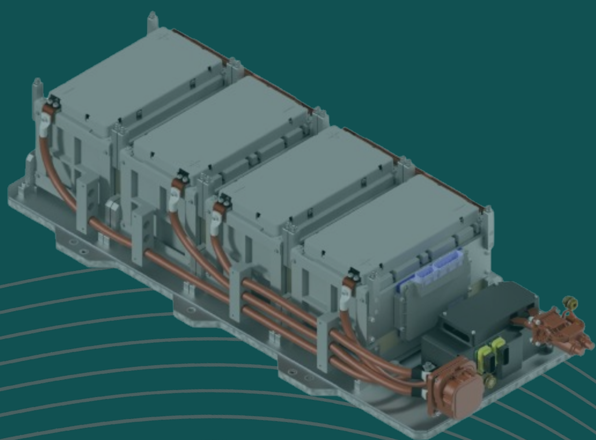




COBRA

KEY TECHNICAL, POLICY AND MARKET DEVELOPMENTS INFLUENCING THE ELECTRIC VEHICLE BATTERY LANDSCAPE





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VALUE FROM SCIENCE AND TECHNOLOGY

BATTERY HOUSING

MARCH 2024

INTRODUCTION

Battery housing for electric vehicles (EVs) has evolved significantly in recent years, helping increase energy density, thermal efficiency, safety, and circularity, while simultaneously reducing costs. Given that some of these battery characteristics contradict each other, researchers and manufacturers are in a constant search for new housing solutions that offer favourable trade-offs for customers and maximise benefits from the introduction of new cell technologies (e.g. solid-state). The most popular innovation areas include lightweight materials, cell-to-pack design, and modularity.

This market intelligence report showcases the latest technical developments in these innovation areas. We also explore the cost breakdown of pack components, as well as analyse key European battery pack producers. In addition, Aentron and THI-Carissma provide insights into the developments within the COBRA project, focusing on battery pack weight reduction, modularity, fire retardancy, and sustainability.

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OVERVIEW

BATTERY HOUSING FUNCTIONS

Battery housing (otherwise known as battery enclosure) influences several critical functions and performance indicators of an electric vehicle (EV) battery.

SAFETY

Battery housing significantly influences safety by providing physical protection, electrical insulation, and environmental resistance. In the event of cell failure (e.g. thermal runaway), the housing acts as a containment vessel, minimising the spread of hazards such as burning, electrocution, the release of toxic gases, and explosions. Additionally, the housing protects the battery system from the impact of external factors, such as mechanical forces during collisions, and ingress of water and dust during usage. Each battery pack must be tested and certified before being placed on the market. The most important safety standards include **UN ECE R100**, **UL 2596**, **ISO 26262**, **IEC 62133**, **ISO 26262,** and **UN 38.3.**

ENERGY DENSITY

High energy density is one of the key targets of battery pack manufacturers. It denotes the capacity a battery can store per unit of **mass** (gravimetric energy density), or **volume** (volumetric energy density). Achieving high energy density allows for a reduction in battery weight, which improves vehicle performance, reduces the space needed for the battery (thereby providing extra functional space for vehicle passengers), and increases the vehicle's range. The leading battery pack solutions on the market reach a gravimetric energy density of **160 Wh/kg** and volumetric energy density of **350 Wh/l**.

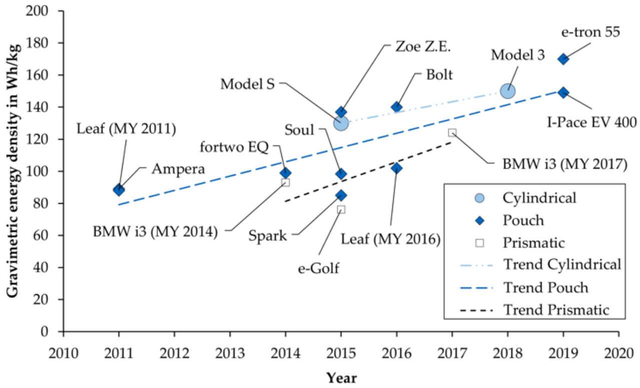


Figure 1: Overview of gravimetric energy density at pack level for different BEVs **[1]**

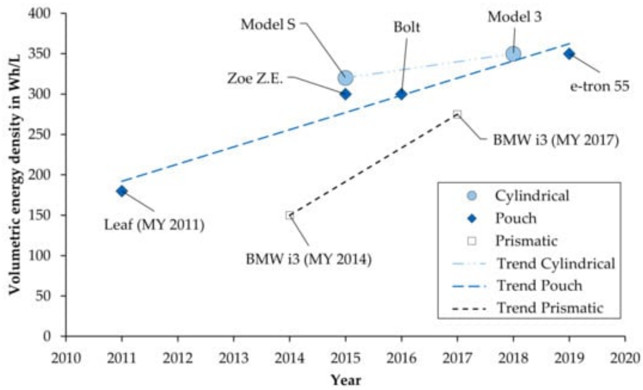


Figure 2: Overview of volumetric energy density at pack level for different BEVs **[1]**

THERMAL MANAGEMENT

Battery cells must operate within specific temperatures (usually between 20°C - 40°C) to maintain high performance, longevity, and prevent thermal runaway. Each EV battery pack has a thermal management system that enables the cooling and heating of batteries during charging and discharging. The battery housing design plays a crucial passive role in supporting the thermal management system: the proper **arrangement of cells** and usage of **thermal interface materials** (TIMs) help exchange and dissipate heat efficiently.

STRUCTURAL SUPPORT

The battery housing significantly enhances the structural stability of the EV through its integration into the chassis, providing rigidity and stiffness, supporting load-bearing functions, and minimising NVH levels (Noise, Vibration, and Harshness) levels. Positioned low in the vehicle's structure, the housing lowers the centre of gravity, improving stability and handling. Additionally, the housing distributes weight evenly across the vehicle and improves load-carrying capacity.

MAINTENANCE

The battery pack is not intended to remain in the electric vehicle forever. In the event of issues, the battery pack or any of its components should be **easily accessible by technicians** for efficient inspection, maintenance, and repairs. This accessibility is facilitated by features such as serviceable panels, connectors, and mounting hardware. Serviceable and modular designs, which include accessible service panels, connectors, and mounting hardware, reduce downtime and labour costs associated with battery maintenance tasks. These designs also contribute to the sustainability of the battery by improving the efficiency and reducing the costs of recycling and repurposing.

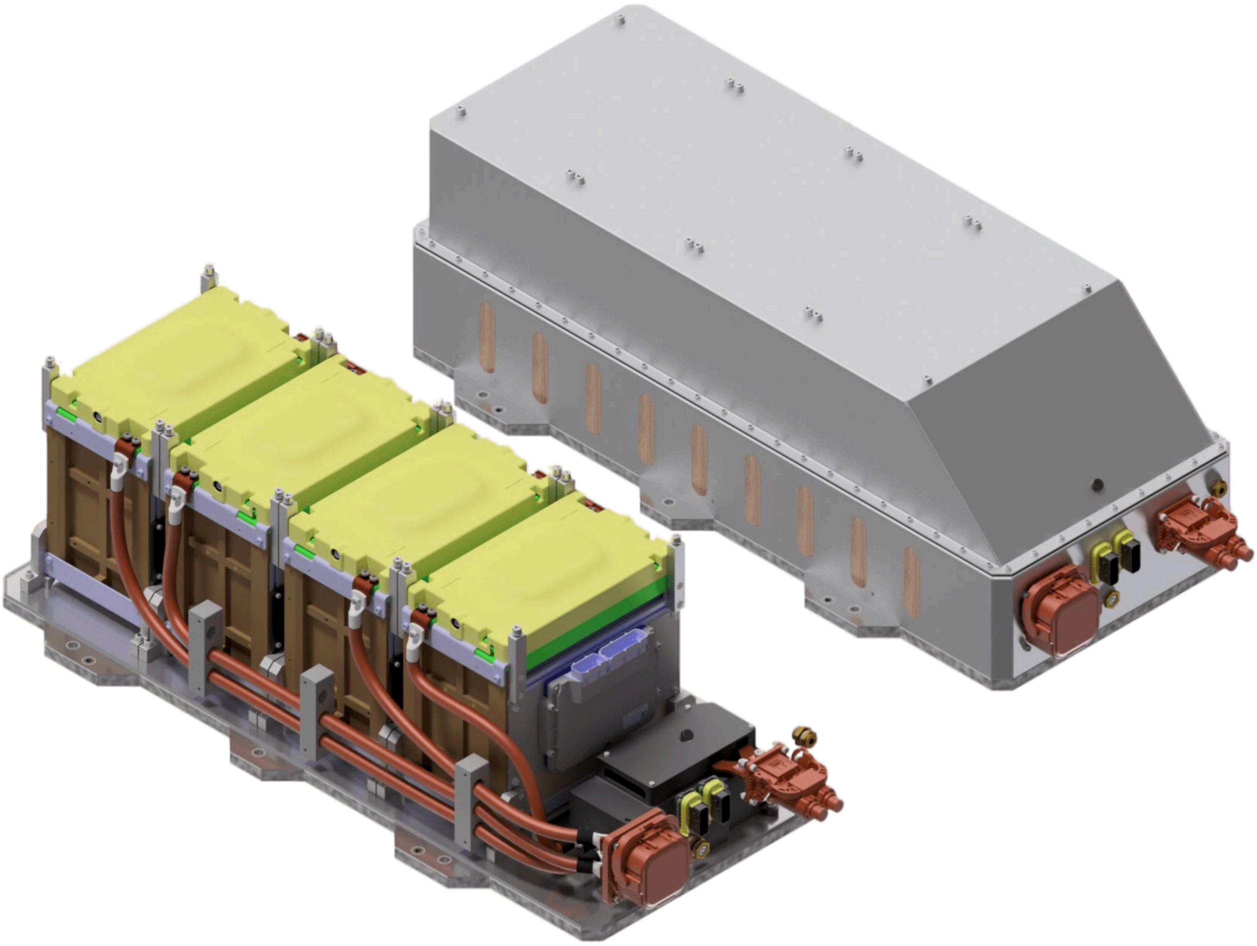


Figure 3: COBRA battery pack with and without external casing – rendered design prepared by Aentron

INNOVATION AREAS AND CHALLENGES

To fulfil the functions outlined in the previous chapter, battery pack researchers, designers, and producers are exploring new solutions across various areas.

LIGHTWEIGHT MATERIALS

While pack enclosures are traditionally made from steel and aluminium, adhering to strict safety regulations, some researchers and companies are venturing into the use of composites, e.g. **injection moulded polypropylene with glass fibres**. For instance, SABIC developed a top cover for the Honda CR-V PHEV battery pack using this material, achieving a 10% weight reduction and a 10% cost saving compared to a conventional steel solution with a thermal blanket **[2]**. Other sustainable materials being tested include **natural fibre-reinforced bio-based plastic** in the BIOBATTERY project **[3]**, and the inclusion of **wooden panels**, an approach successfully tested in the BioLIB project **[4]** and COBRA project, which led to significant weight reduction (Figure 3). The bottlenecks in adopting lightweight materials lie in fire retardancy and manufacturability, particularly for composites.

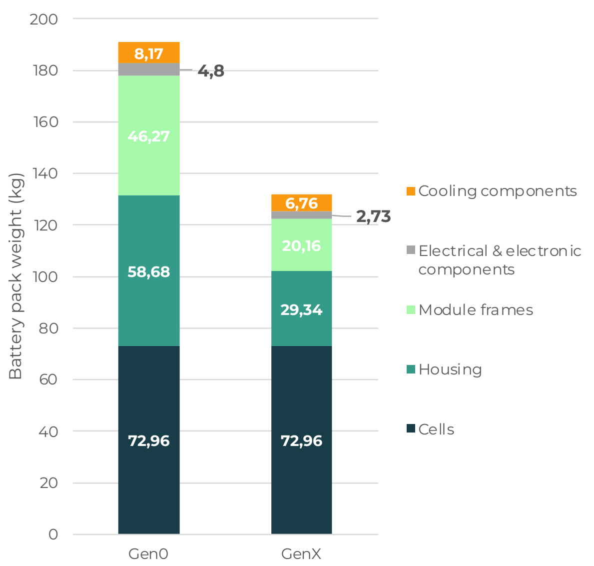


Figure 4: Weight breakdown of COBRA battery pack (capacity: 15,7 kWh)

THERMAL MANAGEMENT

There is a growing interest in passive thermal management systems as an alternative to active Battery Thermal Management Systems (BTMS). These systems offer operational advantages, though they are not yet widely used in electric vehicles (EVs). Two notable passive solutions are **phase change materials (PCMs)** and **heat pipes (HPs)**. PCMs, particularly those undergoing solid-liquid phase changes, are favoured for their high energy absorption and stable temperature characteristics. However, they suffer from low thermal conductivity, prompting research into enhancing heat transfer by embedding them in porous structures or doping with nanoparticles. Despite their potential, PCMs have drawbacks including limited thermal storage capacity and increased battery-pack weight. Heat pipes, which are fluid-filled tubes that utilise vapor-liquid phase change, offer high thermal conductivity and low maintenance. However, their complexity and cost are barriers to widespread adoption. While not commonly used in battery packs, their success in cooling electronic components highlights their potential for BTMS implementation **[5]**.

MODULARITY

Modularity in battery pack design allows for individual components or modules to be easily assembled, disassembled, replaced, or upgraded without impacting the entire system's functionality. This approach also facilitates the easier reuse of batteries, benefiting companies involved in second-life battery applications.

Modularity supports emerging trends such as V2X (Vehicle-to-Everything) with battery swapping or extending battery range (IVECO, CATL).

However, modularity introduces its own set of disadvantages. Additional components, such as connectors and structural elements increase the overall cost, complexity, weight, and energy density of the battery pack. It also presents various technical challenges, such as efficient cooling, electrical connectivity, and integration.

CELL-TO-PACK / CELL-TO-VEHICLE

A distinct, though not necessarily contradictory, approach in battery manufacturing is to minimise the number of modules within batteries. 'Skipping' the module level offers numerous advantages: it simplifies the battery design, significantly increases energy density, streamlines manufacturing processes (thus reducing costs), and enhances cooling efficiency.

This feature is measured by the gravimetric cell-to-pack ratio (GCTPR), which is the total mass of the cells divided by the mass of the complete battery pack, expressed as a percentage. Meanwhile, the volumetric cell-to-pack ratio (VCTPR) indicates the level of space utilisation. Mainstream battery pack modules have on average a VCTPR of 40% and a GCTPR of 60%, while in the latest approaches by Chinese battery manufacturers (such as CATL and BYD), the cells represent over 60% of the volume and 80% of the weight **[6]**.

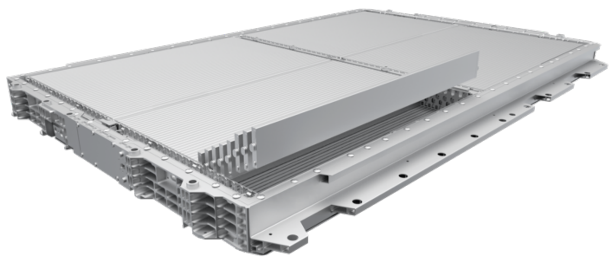


Figure 5: BYD blade cell-to-pack system

Figure 6: Tesla 4680 cell-to-pack design with PUR foam providing rigidity.

The Cell-to-vehicle (also known as cell-to-chassis) approach is the next step of cell integration with the vehicle body, utilising the cell casing as structural support and effectively cancelling out the dead weight of the pack housing.

However, the cell-to-X approaches come with several drawbacks and challenges. Tightly packed cells without partitions need highly efficient thermal management systems, which can add complexity and increase costs. Since module housings also serve as a safety function, their removal also introduces additional challenges, for example, related to thermal propagation in the event of thermal runaway. Additional safety measures are therefore needed for Consequently, extra safety measures are required for cell-to-X approaches. Moreover, where high-power connections are easily grouped per module in current batteries, adopting a cell-to-X approach results in a high number of cables running from the individual cells, making the system less straightforward to refurbish or repair.

SUSTAINABLE AND LIGHWEIGHT BATTERY PACKS

CONVERSATION WITH
SERKAN SEVINC (SCIENTIFIC RESEARCHER AT CARISSMA)
& DENIS HOCK (DEVELOPMENT MANAGER AT AENTRON)

What was your role and objectives in the COBRA project?

Serkan: In the COBRA project, our institute, along with Aentron, led the design of the battery housing using a CFD model and the system integration of all components before the packs were assembled by another partner, Millor Battery. Our objective was to develop a pack using lighter (50% lower weight than steel) and more sustainable (bio-based and recyclable) materials, which would at the same time offer high fire protection (contain at least > 800°C for at least 30 mins).

How did you approach these tasks and what challenges did you face?

Denis: First, we designed a GEN0 pack where the focus was on correct integration and safety. Then for the design of the GENX pack, we looked into various ways to reduce weight, costs, and improve recyclability. On the material side, we decided to use an aluminium foam sandwich material for the base plate which offered a very good strength-to-weight ratio. We also managed to reduce the used volume by a compact arrangement of parts and used the cover of the housing as structural attachment for the modules, to reduce the needed width of the baseplate. Saving even 2cm like this is a significant reduction in base plate weight and an increase in energy density.

Serkan: On the side of sustainable materials, we successfully managed to implement wood panels to the battery pack design which helped us reduce weight. You may wonder though: how is it possible to make wood fire-resistant? We decided to impregnate it with sodium silicate, a non-toxic material which has worked well for fire protection in buildings since the 1850s. The level of flame retardancy that we achieved during abuse tests confirmed that the impregnated wood can withstand strict safety requirements for battery packs. For increased fire resistance, we also used lightweight rockwool panels between modules.

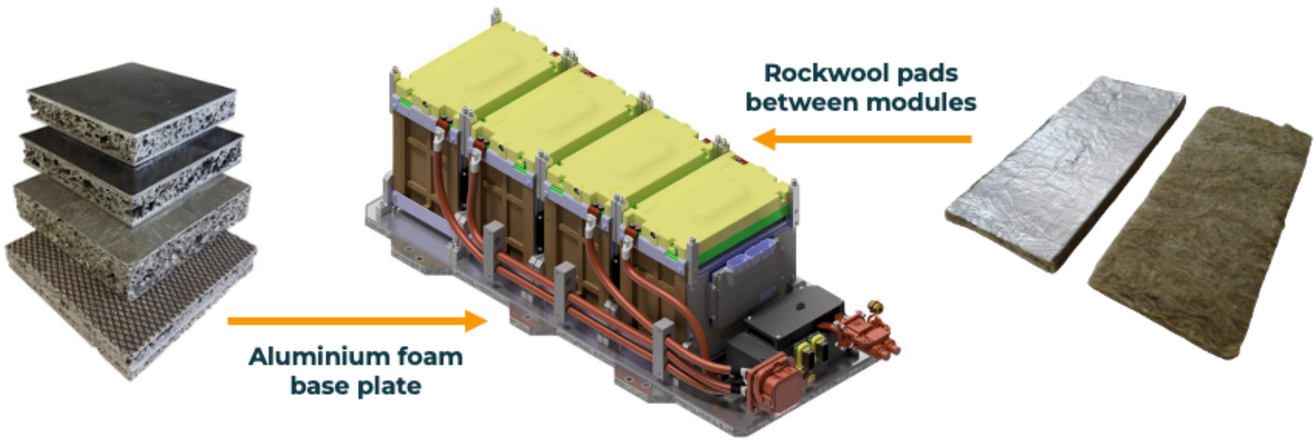


Figure 7: COBRA pack prototype with innovative lightweight materials

Which of the project innovations can be commercialised?

Denis: We believe we can use the space reduction solutions that we explored during the COBRA project in commercial battery packs. Although some material solutions have very promising properties, they still need further development to reduce costs. For example, the aluminium foam sandwich material is, at the moment, too expensive to produce.

Serkan: We received some interest during conferences and meetings with automotive companies about the sustainable materials. We are planning to continue our research in this domain, testing various wood species to explore which type has the best mechanical and thermal properties for battery housing application.

How can the performance of EV battery packs be increased further?

Denis: There are some composite materials like carbon fibre reinforced polymers (CFRP) which have excellent strength and low weight, but they are expensive and far from sustainable because they cannot be recycled. That's why I think aluminium and steel will continue to be the go-to materials for battery enclosures since they offer a good balance between strength, cost, and sustainability. We can see potential in optimised cell arrangements such as the cell-to-pack concept which can dramatically increase the energy density. However, this again often comes together with lower sustainability since less modular packs are more difficult to dismantle, repair, or repurpose. That's why we need to look into design solutions that offer a good balance between all these relevant KPIs.

Figure 8: Abuse test on COBRA pack prototypes

Aentron is a Munich-based SME specialising in the development and production of energy storage devices for maritime, industrial, e-mobility and building power storage applications. Aentron power solutions are state-of-the-art, scalable, robust, and safe from 12V, 24V, 48V up to 900Vdc lithium-ion battery-systems with their own custom battery management system.

CARISSMA is a German RTO specialising in four main research fields: Safe electromobility, Active safety, Integrated safety and Test systems and methods. The 'Safe electromobility' group focuses on ensuring battery system and safety through research on elements like BMS, control units and ESS status recognition. The working group is equipped with test benches up to 800 V and several hundred kW, temperature chambers, climatic chambers, and ion chromatography as well with a battery abuse area.

BATTERY HOUSING MARKET ANALYSIS

COSTS AND MARKET SIZE

Over the past decade, battery prices have seen a significant decrease, affecting both cells and pack components (BMS, enclosure, thermal management, etc.). The proportion of battery pack components in the overall battery cost has reduced from approximately 30% to 20% in recent years. This reduction in the cell-to-pack cost ratio can be largely attributed to advancements in pack design, such as the introduction of cell-to-pack designs. While current commercial housing designs made from steel and aluminium maintain relatively low costs, the adoption of innovations like lightweight materials and phase change materials could lead to an increase in the cost of housing materials. Consequently, this would result in a higher overall cost for the full battery pack and an increased cell-to-pack cost ratio.

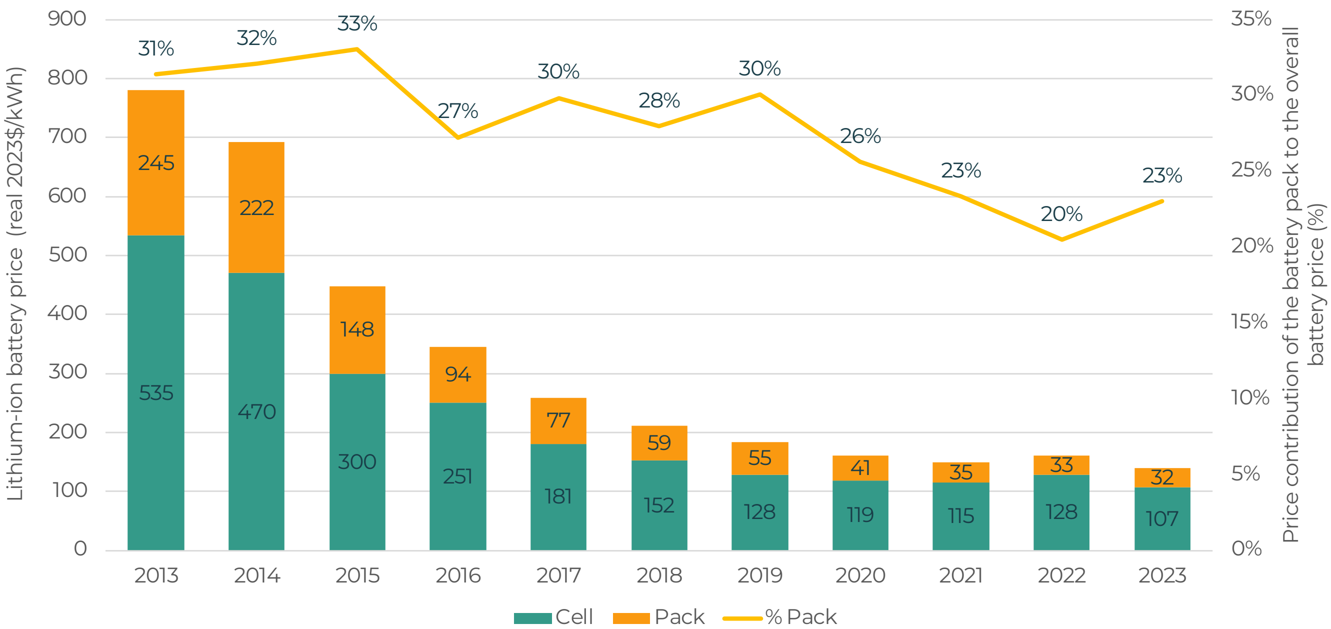


Figure 9: Battery pack price developments (based on **[7]***)*

MAP OF PRODUCERS

Battery housing can range from a simple enclosure roughly adapted to the required shape to more complex designs that include integrated cooling, added structural support, and high functional integration within the vehicle. In examining the landscape of producers, we observe close collaborations between OEMs (Original Equipment Manufacturers) and suppliers to create highly customised packs. These are designed not only to fit the shape of the cells and modules inside but also to integrate seamlessly with the vehicle's design.

The following overview highlights EU pack producers and, by extension, includes several battery housing manufacturers. However, it's important to note that some of the companies listed rely on suppliers for the production of battery housing, and many of these suppliers are not mentioned on the map. Suppliers not listed include Constellium SE, Gestamp Automoción, S.A., GF Casting Solutions, Minth Group Ltd., Nemak S.A.B. de C.V., Norsk Hydro ASA, Novelis Inc. (Hindalco Industries Limited), Proterial, Ltd., Teijin Automotive Technologies, thyssenkrupp AG, TRB Lightweight and UACJ Corporation.

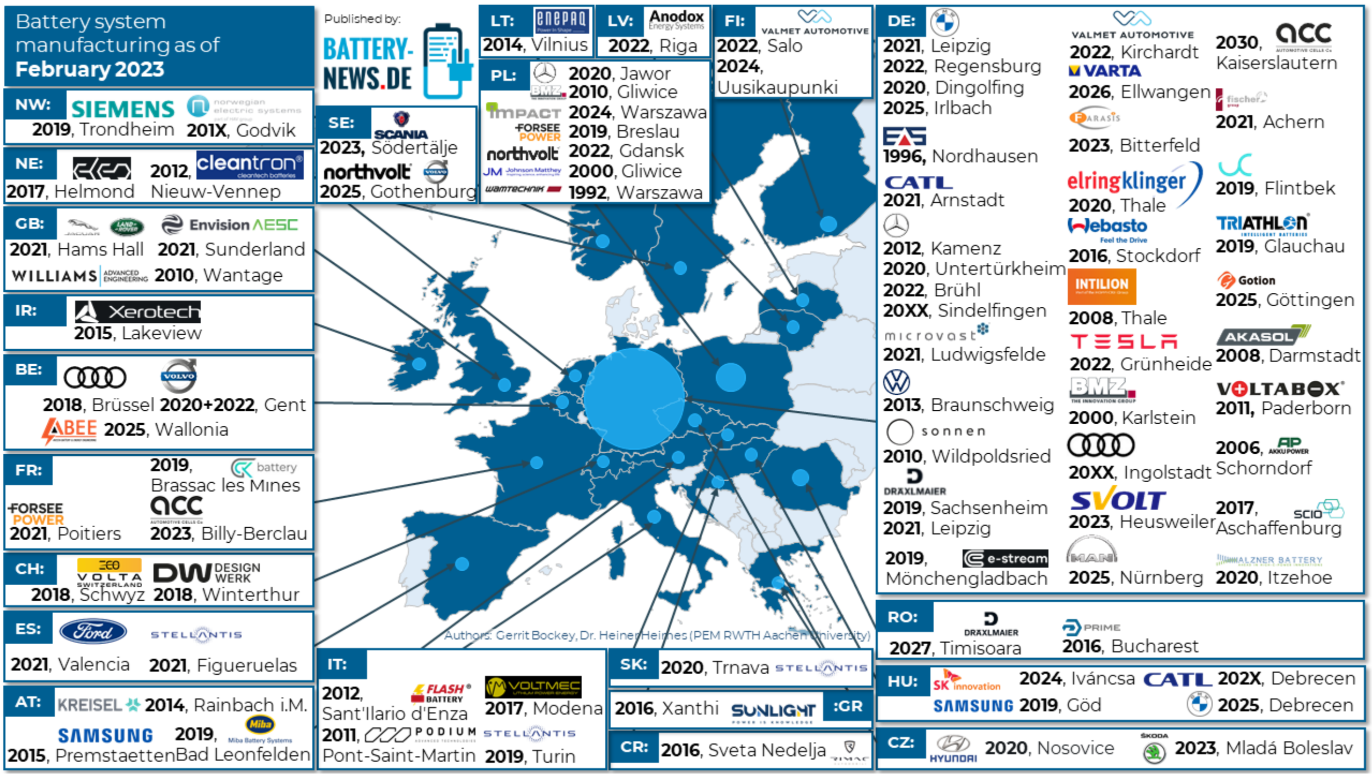
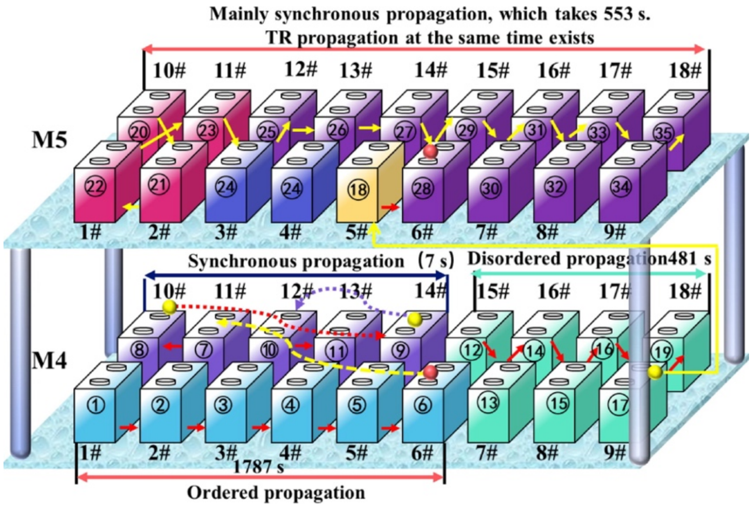


Figure 10: Battery pack and module manufacturers in Europe **[8]**

TECHNICAL DEVELOPMENTS

THERMAL RUNAWAY PROPAGATION OF THE CTP BATTERY SYSTEM

This research investigates the thermal runaway propagation characteristics within a Cell-to-Pack battery system, examining temperature response, vent gas and jet flame behaviour, mass loss, and deformation through quantitative analysis methods. The study identified three major propagation patterns: ordered, disordered, and synchronous, with the latter inflicting the most severe damage. Liquid cooling plates between modules didn't prevent propagation, but gaps helped mitigate the spread.



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ENVIRONMENTAL IMPACT OF LIGHTWEIGHT BATTERY PACKS

The environmental impact of power batteries in electric vehicles (EVs) is significant, making emission reduction vital for EV sustainability. Replacing the steel case with lightweight materials, particularly aluminium alloy, and Carbon Fibre Sheet Moulding Compound (CF-SMC), significantly lowers the environmental impact across multiple categories, including global warming potential (GWP), acidification potential (AP), abiotic depletion potential (ADP(f)), and human toxicity potential (HTP). Sensitivity analysis underscores the environmental benefits of aluminium alloy, highlighting a potential reduction of 1.55 tons in greenhouse gas emissions.

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DEVELOPMENT OF A LIGHTWEIGHT AND CRASHWORTHY CELL CONFIGURATION METASTRUCTURE

Indonesian researchers have explored various metastructure configurations and material types to develop a lightweight, crash-worthy battery protection system with excellent energy absorption capability. Through comparing different configurations and using neural networks to generate the optimal design, they identified the star-shaped auxetic design as having the highest specific energy absorption, as confirmed by Finite Element Analysis.

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MARKET DEVELOPMENTS

BYD AND CATL DRIVE LFP CELLS COSTS DOWN TO $70/KWH

CATL and BYD are aggressively reducing battery costs, offering high-performance VDA-sized LFP cells at competitive prices. The intense competition has led to a notable price decrease, from RMB 0.8-0.9/Wh to around RMB 0.5/Wh ($70/kWh). Prices are anticipated to continue dropping towards RMB 0.3/Wh, prompting manufacturers to prioritise market share over profitability.

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ELECTRODE-TO-PACK TECHNOLOGY DEVELOPED BY MIT SPIN-OFF

24M, an MIT spin-off, unveiled its 24M Electrode to Pack (ETOP) system at the Japan Mobility Show. The system aims to streamline battery pack assembly by integrating electrodes directly into the pack, eliminating the need for individual cells and modules. 24M claims this method will enhance energy density and reduce costs compared to traditional lithium-ion battery production. Collaborations with companies like Freyr and Volkswagen signal industry interest and potential support for the technology.

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ACC RAISES $4.7 BILLION FOR NEW GIGAFACTORIES IN EUROPE

Automotive Cells Company (ACC) has secured $4.7 billion in funding to construct three lithium-ion battery gigafactories across Europe, with backing from shareholders Stellantis, Mercedes-Benz, and Saft. By 2030, ACC plans to manufacture 2 million Li-ion batteries a year. The funding will facilitate the expansion of production lines in France, Germany, and Italy, positioning ACC alongside other lithium-ion producers like Northvolt, which also announced a $5 billion green loan for its expansion.

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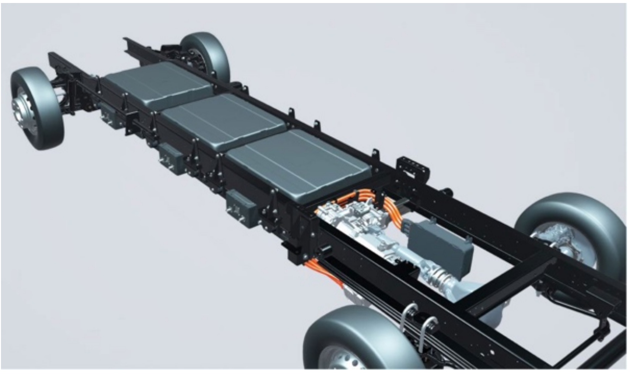
IVECO E-DAILY UPDATE FEATURING PACK EXPANSION UP TO 148 KWH

IVECO has updated the e-Daily van, which offers various battery capacity options (37kWh, 74kWh, 111kWh or 148kWh) through modular packs that fit into the chassis slots. This provides customers with flexibility to adjust battery capacity as the vehicle's mission changes. IVECO technicians can assess battery degradation and fit a used battery with similar degradation levels if additional range is required.



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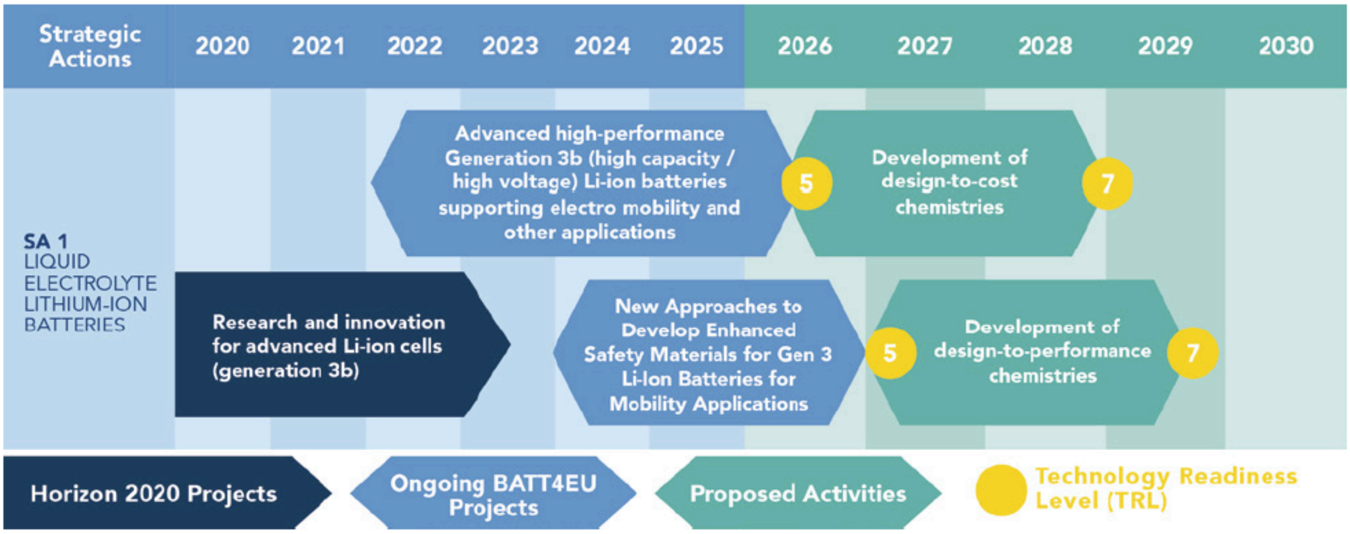
POLICY DEVELOPMENTS

NEW STRATEGIC RESEARCH AND INNOVATION AGENDA

The BATT4EU initiative, in line with the European Commission's objectives, has developed a Strategic Research and Innovation Agenda (SRIA) for 2024. This agenda, a collaborative from numerous European battery experts, guides Horizon Europe work programs and funding, building on previous roadmaps from the Batteries Europe and Battery 2030+ projects. It replaces earlier versions from 2021 and 2020, outlining strategic actions for the European Batteries R&I Community.



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JRC PUBLISHES REPORT ON PERFORMANCE AND DURABILITY

In line with the new Batteries Regulation, the Joint Research Centre published a report in February 2024 setting the groundwork for designing minimum requirements for battery durability in the European market. The report evaluates the interpretation of performance and durability parameters specified in the Batteries Regulation, their measurement specifics, and illuminates the performance and durability of commercial batteries through international standards, manufacturer specifications, and scientific data.

READ MORE

The COBRA project has received funding from the European Union’s Horizon 2020 research and innovation programme under Grant Agreement 875568.

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FEATURE IN A FUTURE REPORT

We’re always on the lookout for contributors! If you’re working in the battery field and share our enthusiasm for advancing battery technology, we’d love to hear from you. Reach out to us at **cobra@baxcompany.com**

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