New modular, recyclable electric vehicles' battery created for second-life use

- **MARBEL project battery prototype design prioritised specially the ease of assembly and disassembly of battery components**
- **Up to 60 percent recycled aluminium has been incorporated, cutting 777 kg of CO_2 equivalent emissions per battery pack**
- **An intelligent system has been created, including a BMS with an AI-driven solution and digital twin capable of predicting a battery's remaining useful life, as well as its state of charge and health**

Barcelona, 28 March 2025 - The European MARBEL project, coordinated by the Eurecat Technology Center with the participation of the Catalonia Institute for Energy Research (IREC), has developed a new battery concept for electric vehicles, focusing on large-scale modular and eco-design principles. The implementation of this approach reduces environmental impact and promotes the circular economy within the automotive industry.

The prototypes' eco-design centred on making battery components easy to assemble and disassemble, directly improving repair efficiency, reuse in other applications, and recyclability. To achieve this, the developed battery packs incorporate up to 60 percent of post-consumer recycled aluminium—equating to a savings of up to 777 kg of CO_2 emissions per pack—and prioritized the modularity to increase the battery and its components lifespan, reducing waste and environmental impact.

Additionally, the prototypes introduce innovations for ultra-fast charging by implementing a cooling system design that ensures uniform heat removal from the cells and busbars, combined with optimization algorithms for the charging process. A switchable Junction Box has also been added to support flexible battery architecture, allowing seamless transitions between 400 and 800 volts and vice versa depending on requirements supporting modularity for both smaller and larger battery packs.

"*The focus on circularity and recyclability creates a pathway to more sustainable electric vehicle technology. At the same time, by optimising battery performance, we address the main hurdles that hinder electric vehicles' acceptance and adoption, such as limited range and lengthy charging times, enabling longer trips,*" says MARBEL Project Coordinator Eduard Piqueras, European Program Manager at Eurecat.

The participation of researchers from IREC involved the development of a cloud-connected wireless Battery Management System (BMS) that enables advanced control features using Artificial Intelligence approaches.

"The target was to develop a smarter BMS to increase the battery performance while making a more compact system design by removing all cabling and wiring harnesses from the pack," highlights Lluís Trilla, deputy head of the Power Systems group at IREC.

Second life for batteries and end of life

A key element tackled by the MARBEL project has been to extend battery life through second-life applications, enabling their reuse, recyclability and refurbishment for energy solutions beyond automotive purposes.

"*By integrating eco-design principles such as modularity, second-life applications, and materials with a high percentage of recycled content, MARBEL has extended battery usage while maintaining material value, effectively reducing waste and advancing both sustainability and economic viability,*" explains Violeta Vargas, researcher in Eurecat's Waste, Energy, and Environmental Impact Unit.

MARBEL has also integrated advanced materials' recovery strategies to reclaim high-purity graphite, lithium, nickel, manganese, and cobalt of the end-of-life cells, complying with the European Regulation on "Sustainability Rules for Batteries and Waste Batteries".

The innovative BMS design led by IREC brings the necessary flexibility to adapt effortlessly the battery to second life applications. With this new approach the battery can operate in a single module, ideal for light urban e-mobility purposes for instance and also allows to stack battery packs targeting grid-connected Front-the-Meter applications.

Smart architecture

The prototypes developed feature an intelligent architecture that use busbars for power connections. These busbars can be easily assembled and disassembled with standard screwed fasteners, and their flexible formats have been refined to simplify assembly operations and withstand potential vibrations in the vehicle's battery pack.

Moreover, the Battery Management System (BMS) includes wireless communications and real-time smart energy monitoring, significantly reducing weight, cost, and design complexity. Specifically, an intelligent electronic device (iSCM – intelligent Smart Cell Manager) has been developed for each battery cell, allowing local cell monitoring and direct communication with the BMS through Bluetooth technology.

For instance, in a 16-cell battery pack, wiring can be reduced from more than 20 meters to just 80 centimetres, lowering material costs, weight, and assembly complexity, while enhancing overall efficiency.

Data collected by the BMS, together with information generated by the iSCM, is fed into a digital twin driven by artificial intelligence and machine learning algorithms, enabling predictive analytics by combining multiple data sources in a single web-based application. The system can predict remaining battery life, state of charge and health, and estimate when the battery will reach the end of its lifespan, among other key

parameters. This allows for the availability of reliable information to plan a second useful life based on the health status of the components.

Thanks to this novel approach researcher from IREC estimate that the automation of battery pack assembly can be easily adopted driving down costs, additionally, it opens the door to even more energy dense approaches such as cell-to-pack configurations, moving away from the module-based current designs.

About MARBEL

The project has received funding from the European Union's Horizon 2020 program. The MARBEL consortium includes 16 partners across eight countries: six universities and research centres (Eurecat, project coordinator; the Catalonia Institute for Energy Research (IREC); SINTEF; ICCS at the National Technical University of Athens; Technische Hochschule Ingolstadt; and Fraunhofer IWU), one automotive engineering company (Applus IDIADA), two SMEs (Powertech Systems and OTC Engineering), one OEM (Stellantis – CRF), and five component manufacturers (FICOSA, AVL Thermal HVAC, AVL Italia, ASAS, Agrati, and SK Tes).

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