FREE4LiB

Feasible REcovery of critical raw materials through a new circular Ecosystem FOR a Li-Ion Battery cross-value chain in Europe.

CLUSTER HUB
PRODUCTION OF RAW MATERIALS FOR BATTERIES FROM EUROPEAN RESOURCES

Annual Meeting

20th November 2025

Juan Castro - Project Coordinator

SCAN ME

[TECHNOLOGY CENTRE] CARTIF

Funded by the European Union

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Project overview

General Information

Feasible REcovery of critical raw materials through a new circular Ecosystem FOR a Li-Ion Battery cross-value chain in Europe.

www.freeforlib.eu

Funding: Horizon Europe – Grant Agreement No. 1069890

Call: HORIZON-CL5-2021-D2-01

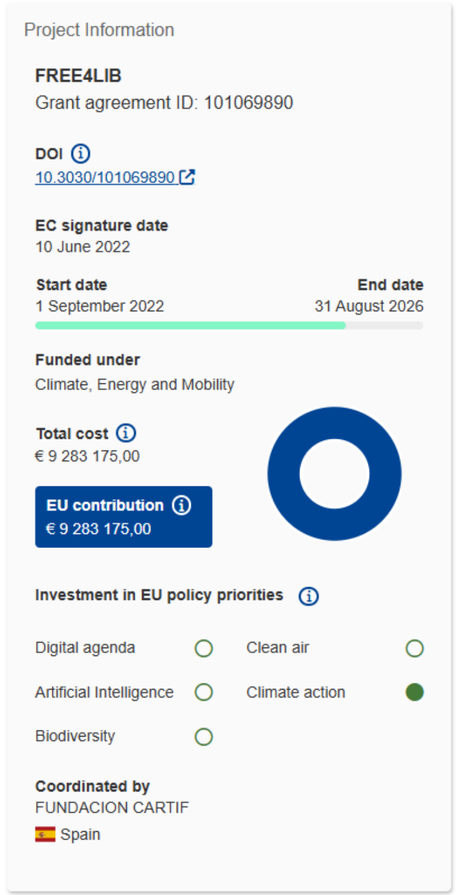
Topic: HORIZON-CL5-2021-D2-01-06 - Sustainable, safe and efficient recycling processes (Batteries Partnership)

Duration: 4 years (from September 2022 to August 2026)

EC Contribution: 9.3 M€

Partners: 22 from 7 different countries

Coordinator: CARTIF



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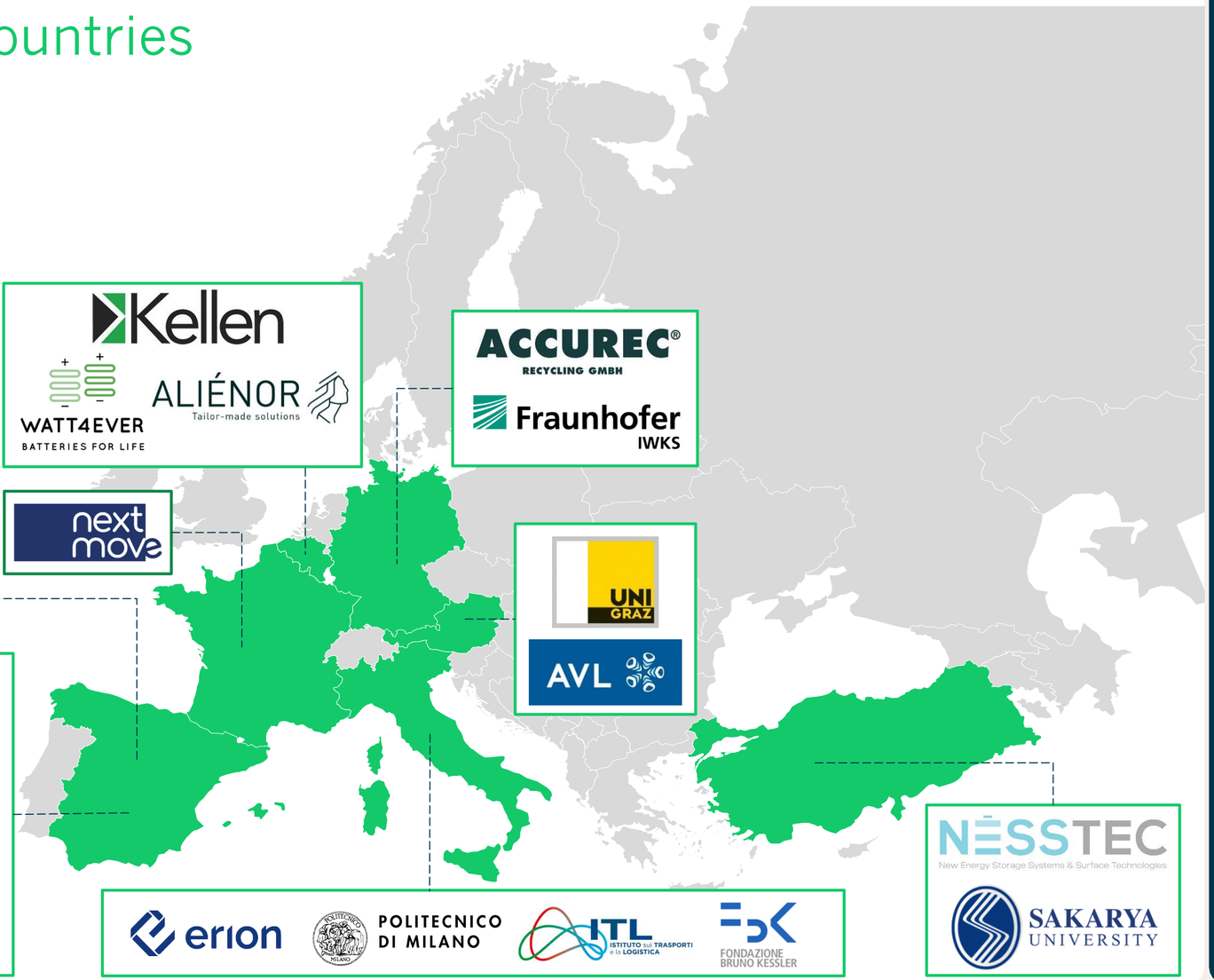
The Consortium

22 partners from 7 countries

Coordinator

Beneficiary

9 RTOs
4 SMEs
3 Industrial Companies
2 Associations
2 Public Organisations
2 Non-profit Organisations



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Project Objectives

FREE4LIB aims to develop at TRL 5-6 technologies to achieve **6 new sustainable and efficient processes to recycle end-of-life LIBs (dismantling and pre-treatment), and 4 materials recovery processes.**

Delivering very innovative recycling solutions **to reach highly efficient materials recovery** (metal oxides, metals and polymers) improving the supply of secondary resources at EU level.

FREE4LIB also will deliver technologies **to improve 3 processes aiming at metals and polymers re-using and electrode synthesis** on the same value chain as secondary raw materials for re-manufacturing greener batteries, and it will study options to harness non-reusable elements in other fields.

FREE4LIB will also deliver a methodology based on the **Battery Passport** principles to improve processes' traceability.

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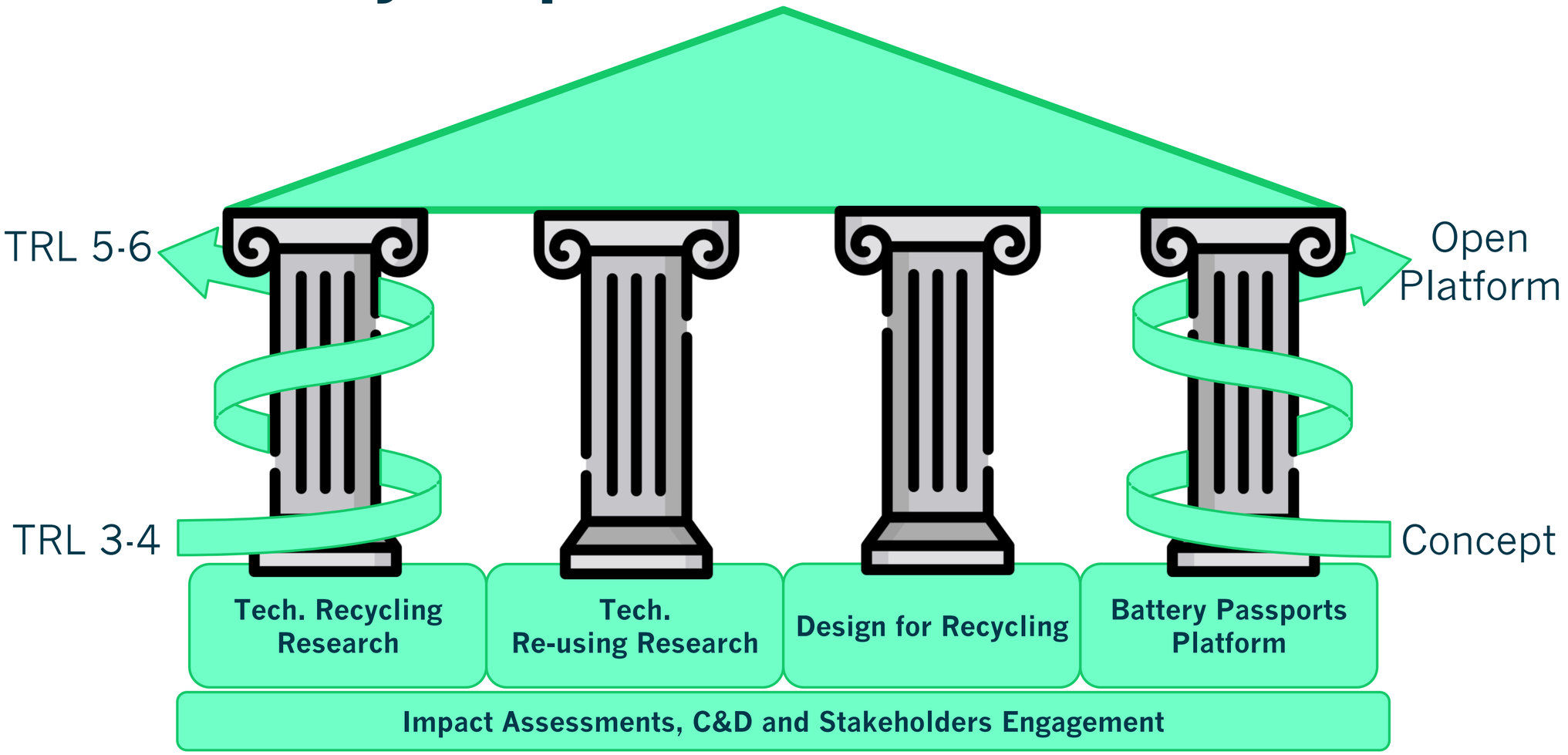
Main Project pillars



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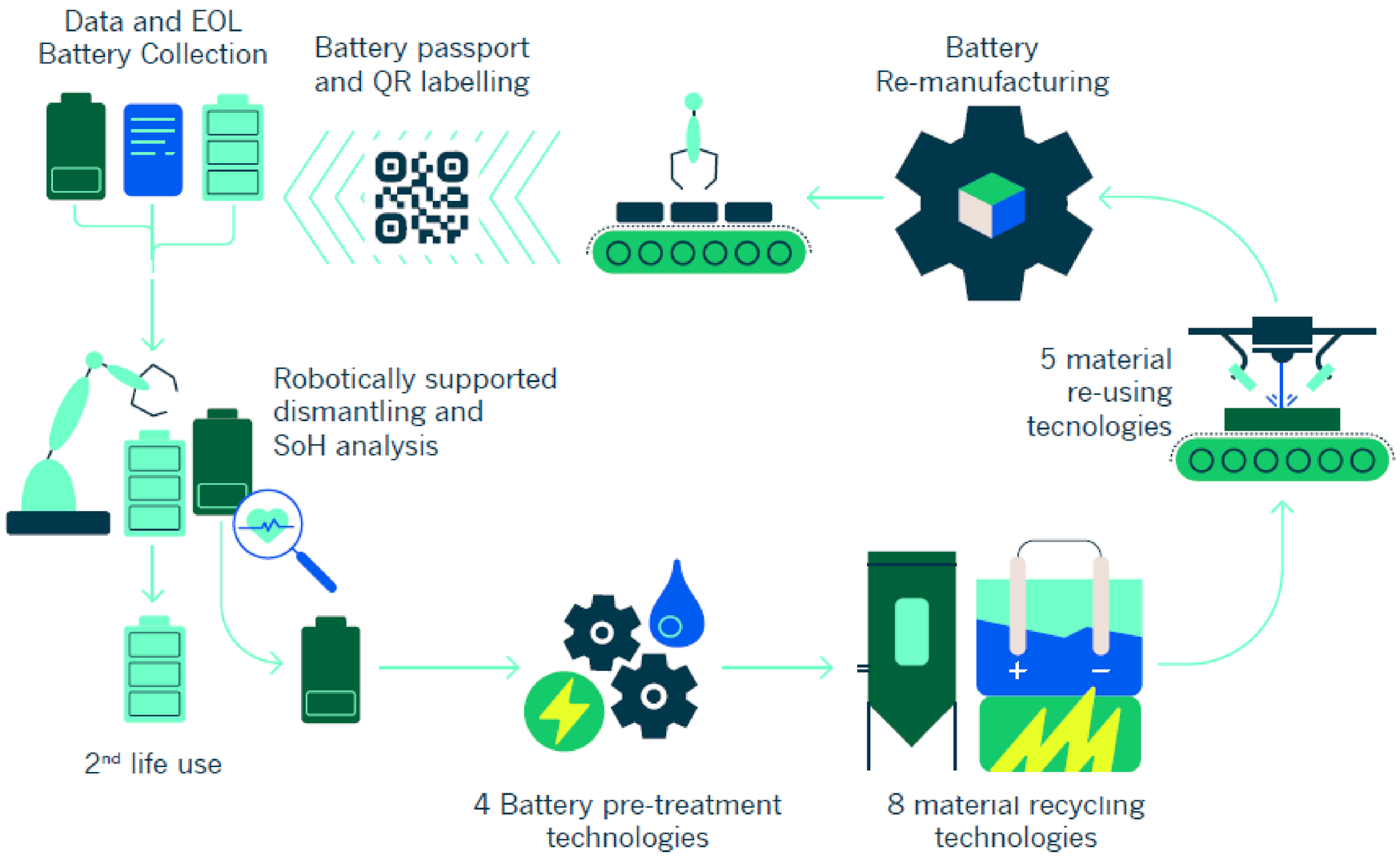
FREE4LIB concept



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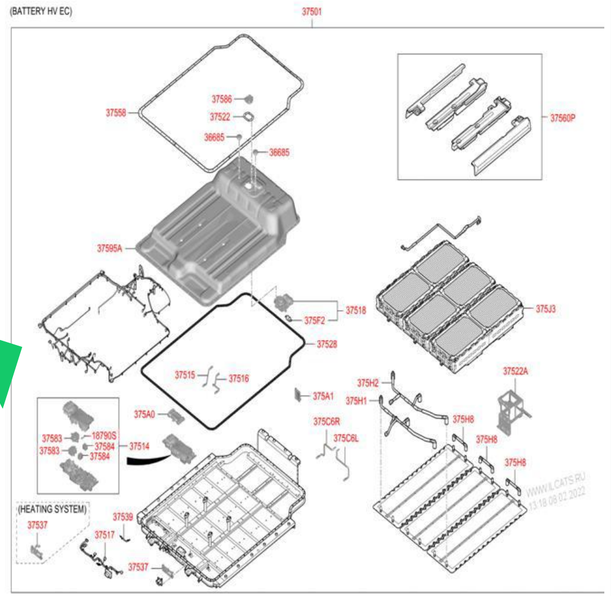
Achieved results on:

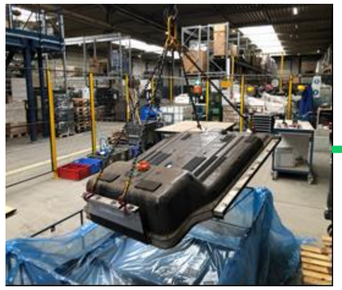
Dismantling from Electric Vehicle

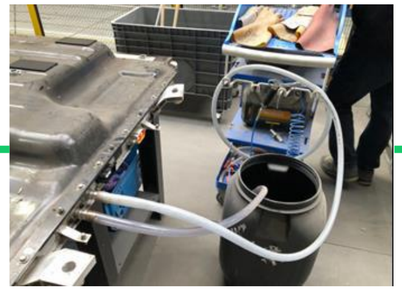
Manual Dismantling and implementation opportunities

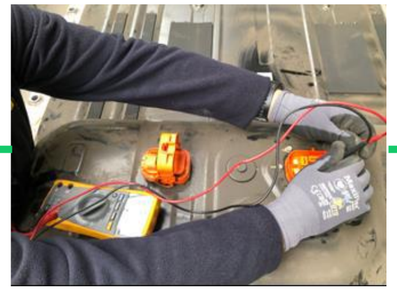
Analysis of the parts of the battery pack for its dismantling and further implementation with robotics.

EoL LIBs from Hyundai KONA EV – LG E63B cells







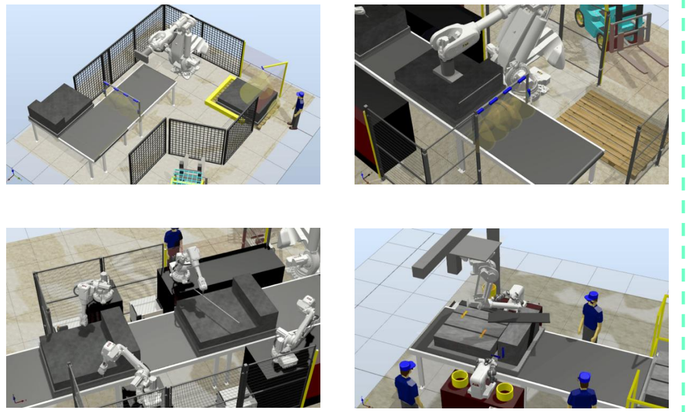


Achieved results on:

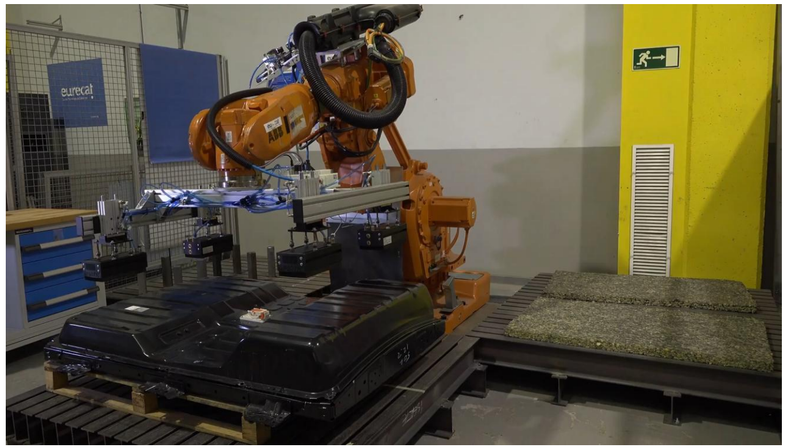
Dismantling from Electric Vehicle

Robotically dismantling achieved at TRL 5 reducing 50% operational time

Risks reduction on lid removal and unscrew activities



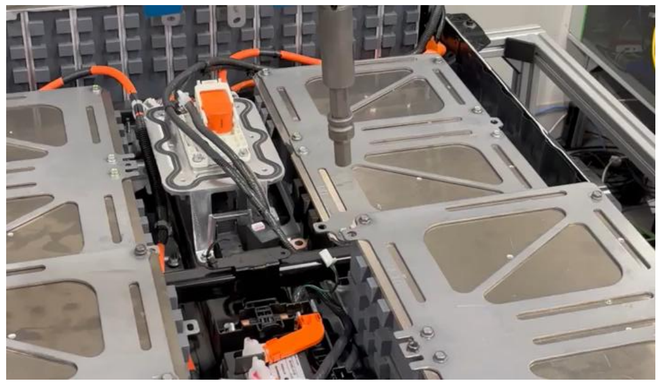
Simulation of the battery pack dismantling



Lid removal task

FULL VIDEO ON YouTube

Unscrew task



Screws identification after robot training

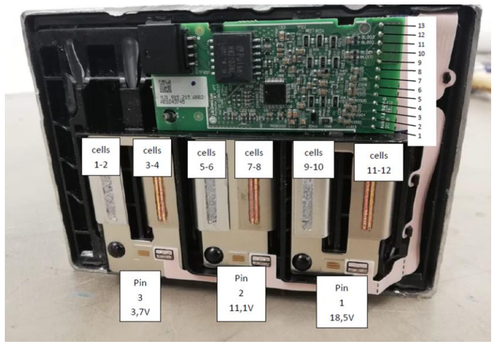
Achieved results on:

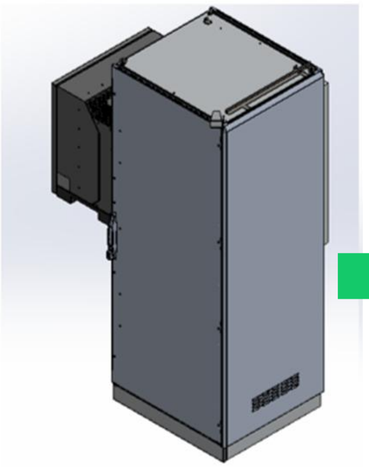
2nd life batteries and SoH tool

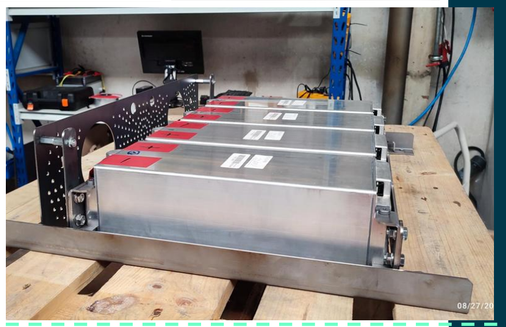
The fast BMS achieved SOH estimation accuracy with a MAPE below 2.5%, reducing test time by over 99%

Cells and modules SoH analysis & evaluation tool

BMS and 2nd life battery prototype design and assembly







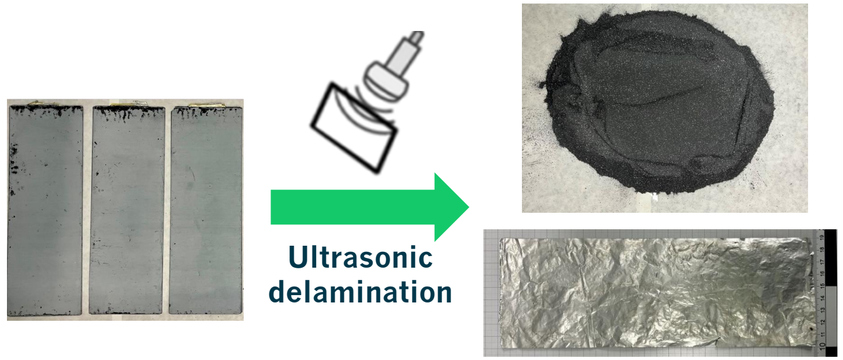
Achieved results on:

Modules and Cells Pre-treatment

The three pre-treatment technologies were implemented and achieved successful results at lab scale

Pyrolysis + Mechanical Shredding is commissioning to 1,000 kg/h

Ultrasonic delamination is being scaling-up to treat entire cells



Electrohydraulic fragmentation (EHF) is moving to new capacities

TRL 4

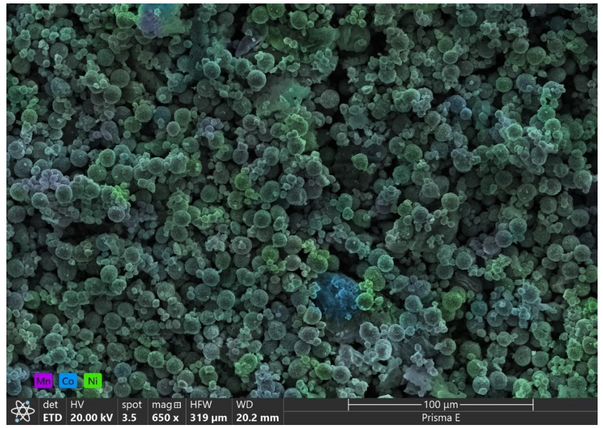
TRL 6

Achieved results on:

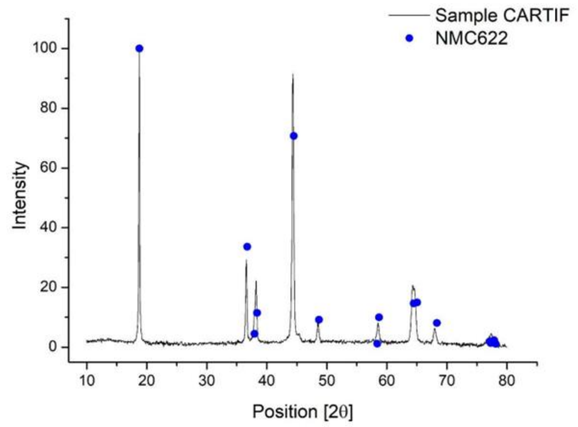
Cathode direct recycling

The hydrothermal route achieved the commercial NMC622 qualities

SEM-EDX result: repaired CAM



DRX result: comparison with commercial NMC622



LiOH

CAM

Hydrothermal reactor

Muffle furnace

Repaired CAM

Achieved results on:

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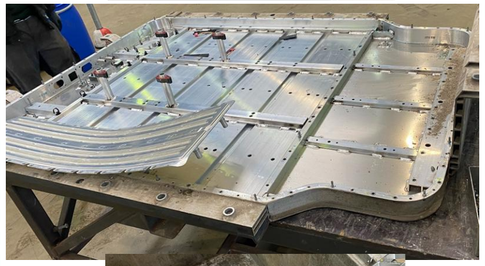
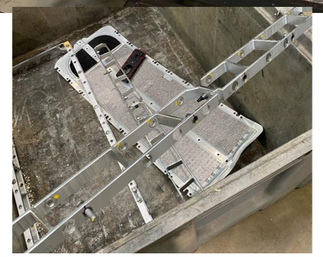
Metals recycling and reusing

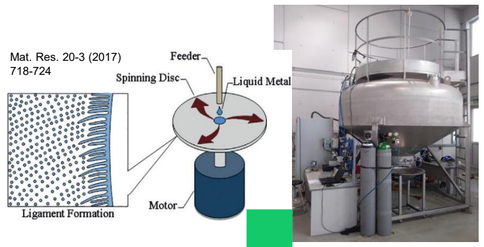
100% recycled materials were used to produce new metal alloys and extruded frames

Feeding metals from EV pack



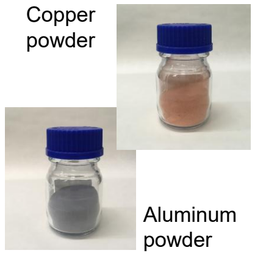


Metallic powder atomization pilot plant

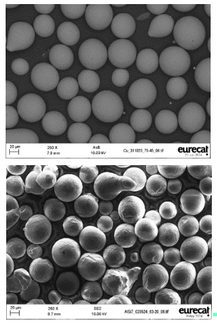


Resulting powder

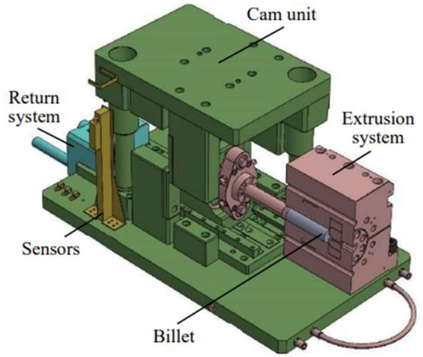
Copper powder

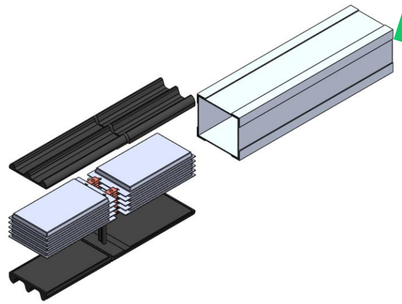


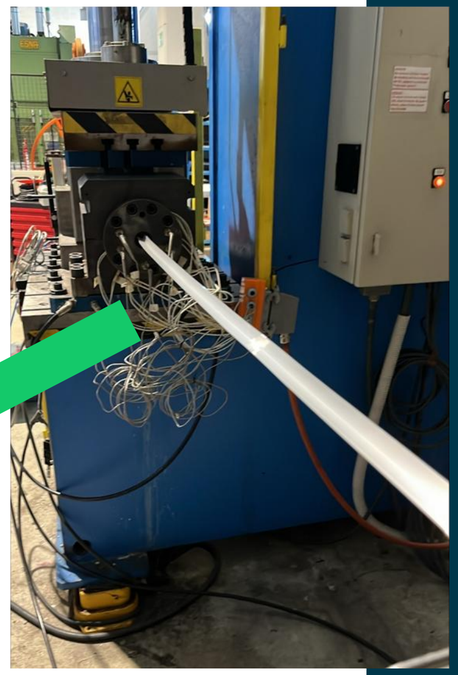
Aluminum powder



Metal extrusion process and use in the FREE4LIB battery pack







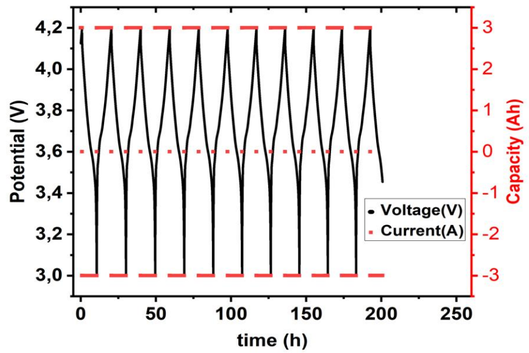
Achieved results on:

Battery pack prototype

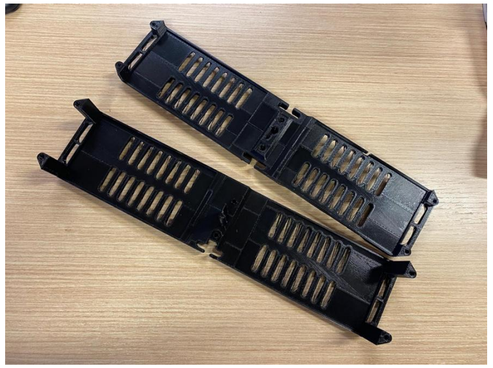
Light mobility was selected to develop FREE4LIB battery packs with recycled materials based on DfR guidelines

E-bike use case

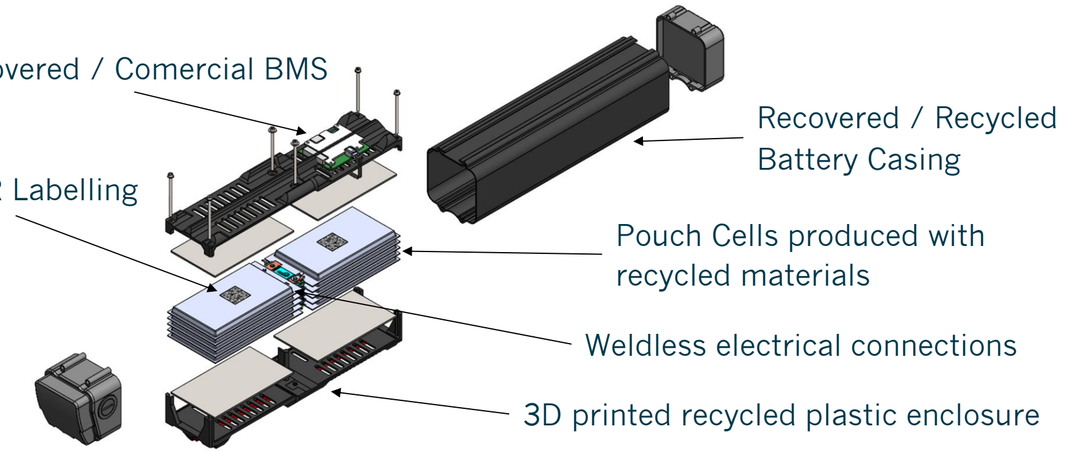
Manufactured Pouch cells for FREE4LIB prototype



3D printing plastics



Prototype design



Achieved results on:

Battery Passports

The second version of the FREE4LIB battery passport platform has been completed.

- **Enhancing usability** by implementing a **role-based access** system and a structured **dashboard interface**.
- **Improving blockchain interactions** by integrating **meta-transactions**, allowing users to interact with the blockchain **without managing gas fees**.
- **Strengthening the backend infrastructure** by refining the API, database integration, and data synchronization with blockchain events.

Achieved results on:

Dissemination metrics

4 Scientific papers published and more than 7 abstracts submitted before end of this year

- Shiea, M., Crema, L., & Gino Macchi, E. (2024). **Modelling of the leaching process by the extended quadrature method of moments**. Chemical Engineering Science, 292(119987). https://doi.org/10.1016/j.ces.2024.119987

- Kaarlela, T., Villagrossi, E., Rastegarpanah, A., San-Miguel-Tello, A., & Pitkaaho, T. (2024). **Robotised disassembly of electric vehicle batteries: A systematic literature review**. Robotised Disassembly of Electric Vehicle Batteries: A Systematic Literature Review, 74, 901-921. https://doi.org/10.1016/j.jmsy.2024.05.013

- Ott, J., Schoeggl, J.-P., & Baumgartner, R. J. (2024). **End of life focused data model for a digital battery passport**. 31st CIRP Conference on Life Cycle Engineering, Turin, Italy. https://doi.org/10.1016/j.procir.2024.01.040.

- Rosso, L., Alcaraz, L., Rodríguez-Largo, O., & López, F. (2024). **Purification of Li2CO3 Obtained through Pyrometallurgical Treatment of NMC Black Mass from Electric Vehicle Batteries**. Chemsuschem, 18(6). https://doi.org/10.1002/cssc.202401722

Open challenges

FREE4LIB project

- Electrode production of LMO and NMC using recycled materials
- Validation of the recycling technologies at the target TRL
- Battery Passport Open Platform running and accessible for the public
- Final event organization in collaboration with sister projects and EU relevant members

Upcoming Horizon calls:

- Continue to work with the developed technologies. Look for higher TRLs (6-7).
- Validate the use of recovered materials in larger light electric mobility cars.
- Continue developing our Battery Passport Platform in line with EU regulations and expectations.

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Thank you

Q&A

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KEEP IN TOUCH

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