Piloting Collection and Treatment Infrastructure for End-of-Life Lithium-ion Batteries: Insights from the FREE4LIB and REBELION Projects

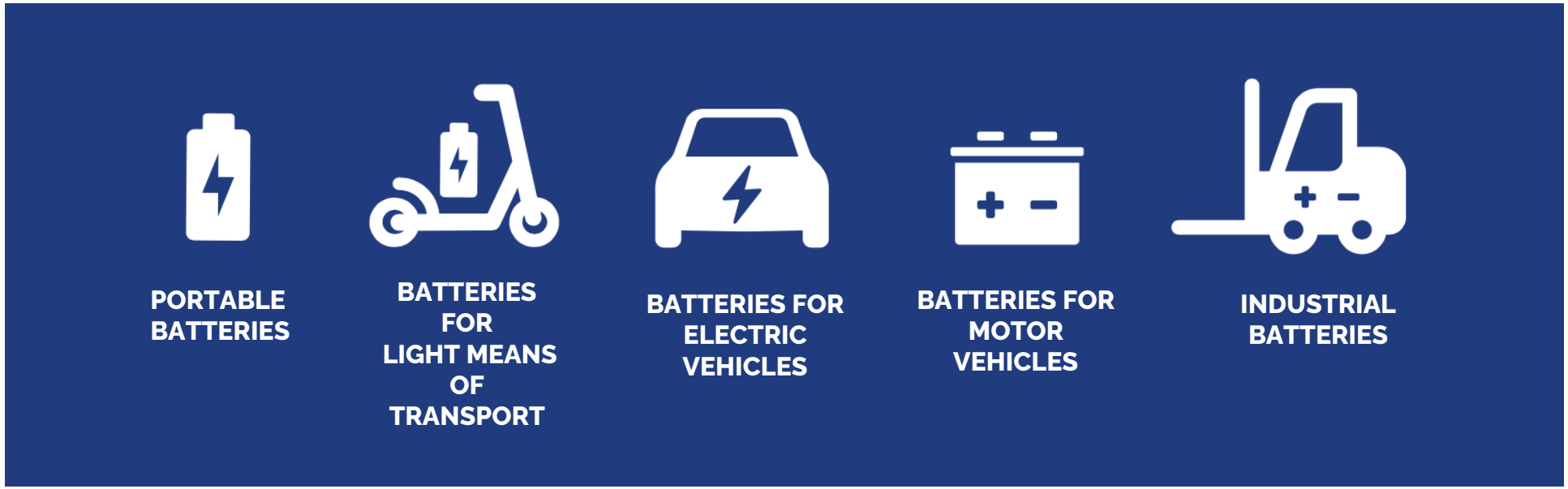
The Erion System

Erion is the leading Italian multi-consortium system for Extended Producer Responsibility (EPR), managing all waste streams related to electrical and electronic equipment and batteries, as well as waste from tobacco products and textiles, with a strong track record in terms of authority, efficiency and quality.

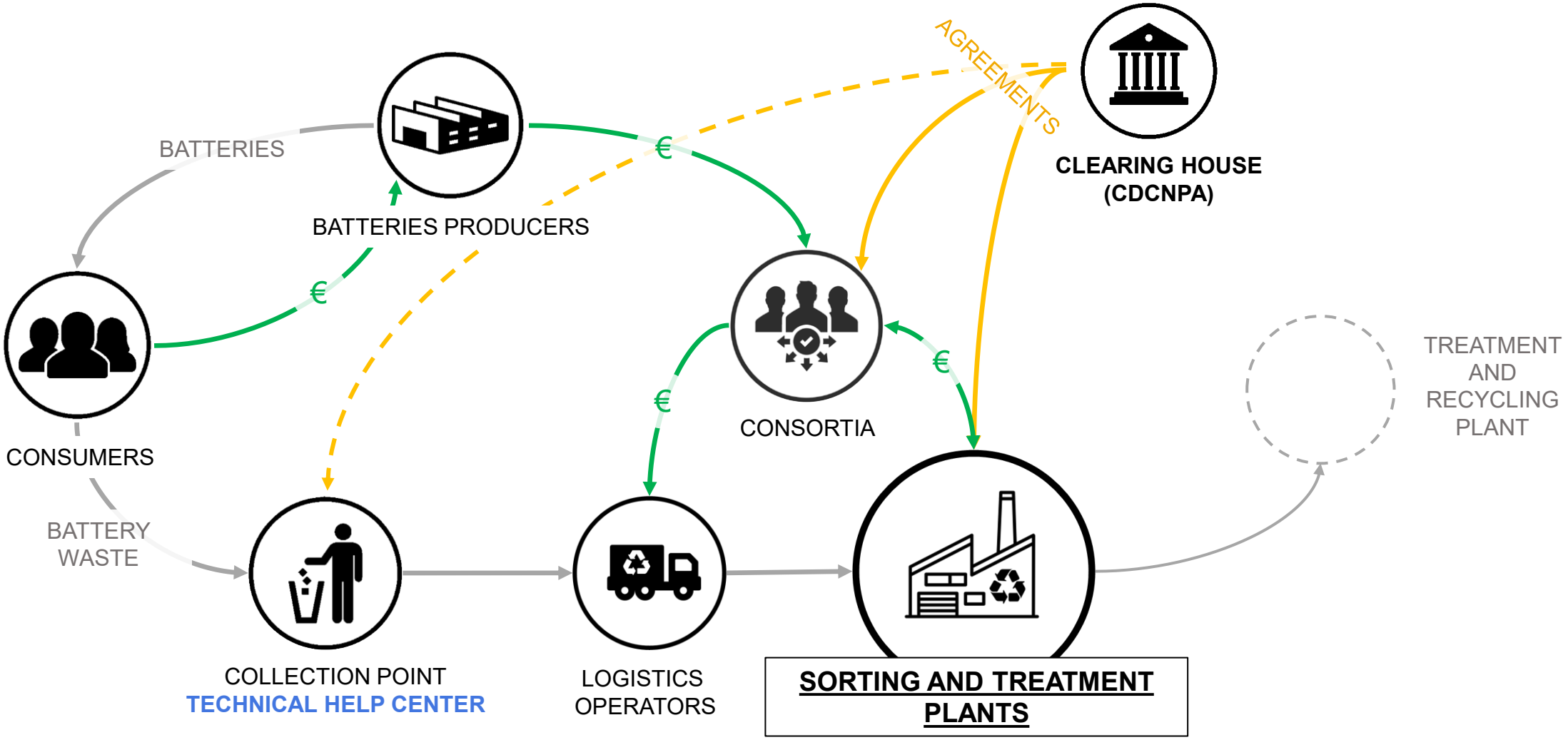
Erion Energy

Erion Energy is **a non-profit Consortium** established by and for Battery Producers to ensure safe, cost-effective and environmentally sustainable compliance with the obligations set out by European and national regulations for the end-of-life management of their products.

Erion is the Producers' System, governed by the Producers themselves.



End-of-Life Value Chain



Strategic Development & Innovation Team

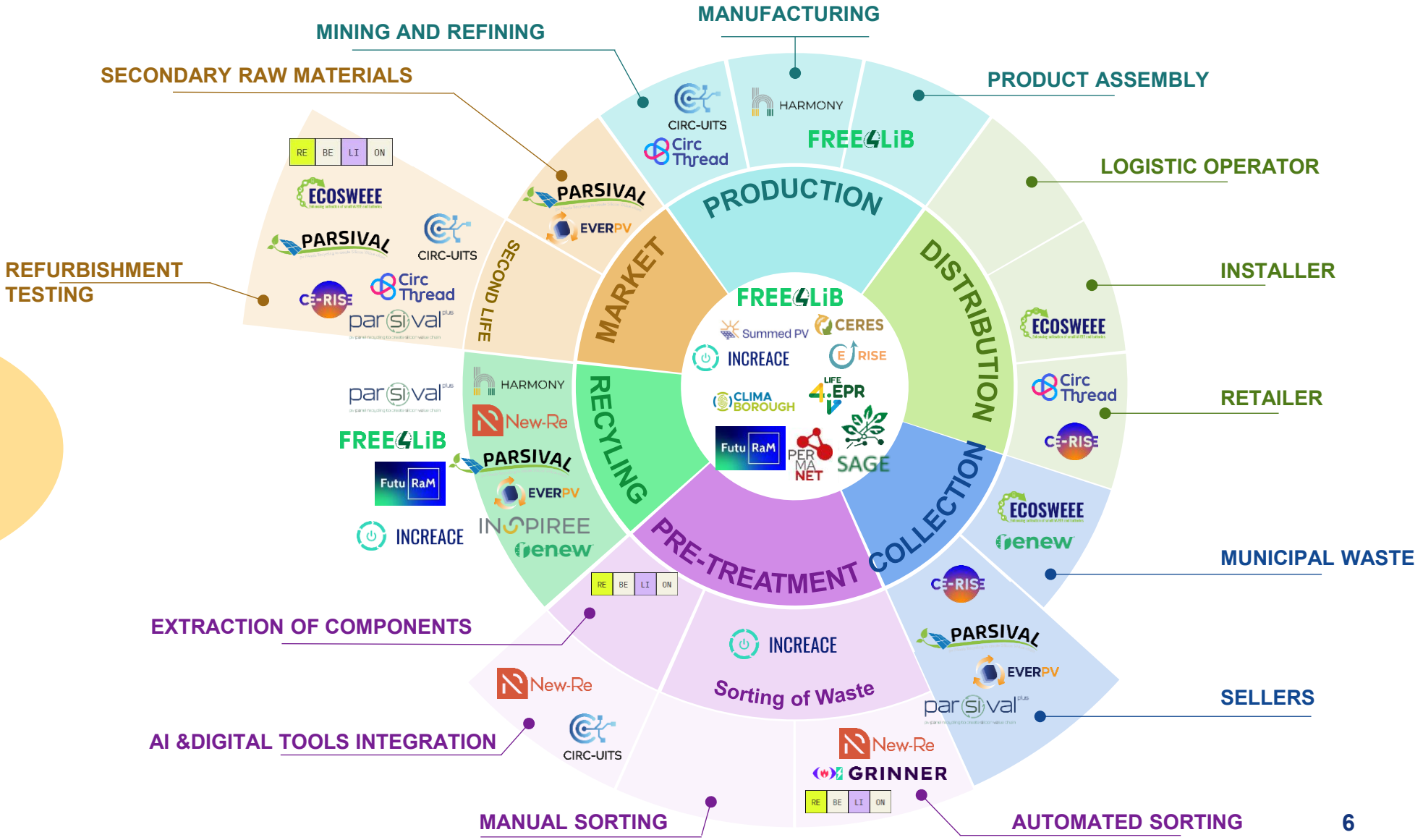
The SDI team is responsible for:

- Management of **European funded projects on circular economy**
- **Research activities** to improve collection systems, waste separation and product eco-design
- Developing **innovative services** for associated producers
- **European educational projects**: from elementary school to higher education

EU-funded projects

Co-funded by the European Union

20 active EU-funded projects 2024-2025



Erion's role in EU projects

Integrated value chain approach for a comprehensive and strategic view

Provision of samples, waste stream mapping, data collection on critical raw materials, in-plant sampling, and recyclability assessments

Support in the creation of pilots for the validation of new technologies and collection systems

EU projects on re-use and recycling of Li-Ion batteries

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Closed-loop recycling: value chain for secondary raw materials

New technologies for **materials recovery**

Cathode **direct recycling**

SHARED GOALS

Circular value chain for spent LIBs

Digital Battery Passport

2nd life applications before recycling: development of **stationary storage units**

Automated robotic dismantling and sorting lines

Smart Containers for battery transport

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“Feasible recovery of critical raw materials through a new circular ecosystem for a Li-ion battery cross value chain in Europe”

CONTEXT

- New Battery Regulation
- Electric Mobility

OBJECTIVES

- Improve recycling processes to achieve **better efficiency and recovery rates.**
- Increase the recovery of Critical Raw Materials from end-of-life batteries in order to reintroduce them into the production of new batteries.
- Design for Recycling of new batteries.

PILLARS

- Collection of EOL batteries
- Technological Development
- Impact Assessment
- Digital Battery Passport
- Stakeholder engagement

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How to improve LMT battery collection?

EU regulation 2023/1542:

- New categories of battery waste: portable, automotive, industrial, **LMT (light means of transport)**, electric vehicle batteries
- New category-specific collection targets:
  - Portable: 63% by 2027; 73% by 2030
  - **LMT: 51% by 2028; 61% by 2031**
- Treatment recycling efficiency targets
- Data tracking through the Digital Battery Passport (DBP)

→ **New collection model to be defined according to value chain needs**

Key steps involving Technical Service Center, Erion and logistics operator:

1. Battery acceptance
2. Diagnosis
3. Storage
4. Transport

➢ Container specifications to increase transport safety

→ Provide Technical Service Centers with dedicated training to ensure safe and effective battery handling

1. Battery Acceptance

When the battery arrives at the Technical Service Center, it is still considered a product; once accepted, it becomes waste.

Battery condition assessment – key questions

- Is the battery **end-of-life or no longer usable**?
- Is the battery **damaged** or **defective**?
- Are there visible signs of **physical damage**, such as dents, cracks, openings, casing deformation or discoloration?
- Has the battery **leaked electrolyte** or shown signs of **venting**?
- Has the battery produced **smoke**, **flames**, **unusual heat** or **gas emissions**?
- Has the battery been misused, overcharged or over-discharged?
- Are **voltage** and **temperature** stable?
- Has the battery been placed in **quarantine** or **safely isolated**?

Categories

- **Defective/non-critical damage**
- **Defective/critical damage**
- **End-of-life battery**

2. Diagnosis

The diagnosis has the aim of:

- Identifying a potential second life for the battery
- Confirming that the batteries are dead
- Determining whether the defective/damaged batteries are critical or not

Batteries found to be damaged or defective, under normal transport conditions, may undergo **thermal runaway** and are susceptible to:

- rapid fragmentation (explosion);
- initiate dangerous chemical reactions;
- produce a flame;
- produce a dangerous development of heat or a dangerous release of toxic, corrosive, or flammable gases or vapors.

The evaluation will be based on **safety criteria**, including:

- Acute hazard (gas formation, fire, or electrolyte leakage);
- Use or misuse of the cell or battery;
- Signs of physical damage;
- External and internal short-circuit protection (voltage or insulation measurements);
- The safety condition of the cell or battery;
- Damage to any internal safety components, such as the battery management system.

Reuse is preferable because:

- It reduces the amount of waste
- It avoids the environmental impacts of disposal
- It prevents the demand for virgin raw materials to produce new batteries

There are no standardized procedures for battery diagnosis yet

3. Storage

Lithium batteries are classified as **NON-hazardous waste**, with **EER code: 16 06 05**. For the purposes of the permitted limits for temporary storage, they are added to other non-hazardous waste and must not exceed 30 m3/year or must be moved on a quarterly basis.

GUIDELINES

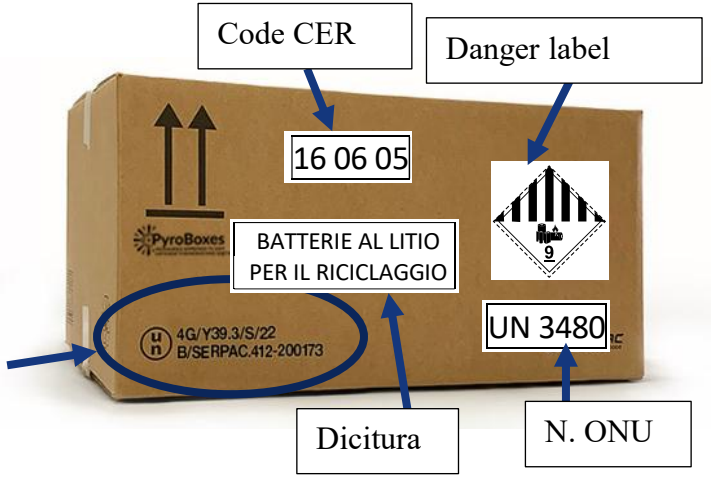
- **Avoid high temperatures** and **excessive humidity** during storage.
- Prefer **outdoor areas**.
- Indoor areas must be ventilated and cool (between 5 and 30°C).
- Place **insulating and fire-resistant components** between batteries, maintaining a separation distance (2.5 m).
- Keep batteries away from batteries that are undergoing charge/discharge cycles.
- Structures must be **heat-resistant** and have **washable surfaces** to remove ash and residue in the event of a fire.

Containers for batteries

End-of-life batteries

The Technical Service Center prepares packages according to the following specifications:

- Marking: UN3480 – LITHIUM BATTERIES FOR RECYCLING
- Label: 
- Packaging instructions P909:
  - P909(1): approved → battery <12kg or battery >12kg but with a non-shock-resistant casing



Non-critical batteries

The Technical Service Center prepares packages according to the following specifications:

- Marking: UN3480 - **DAMAGED/DEFECTIVE** LITHIUM-ION BATTERIES
- Label: 
- Packaging instructions: P908

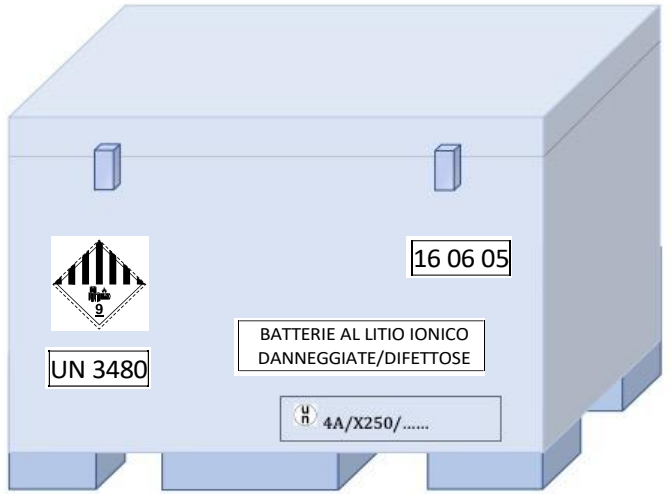
Containers for batteries

Critical batteries

The Technical Service Center prepares packages according to the following specifications:

- Marking: UN3480 - **DAMAGED/DEFECTIVE** LITHIUM-ION BATTERIES
- Label:

- Packaging instructions P911: to be applied on two opposite sides if the packaging volume exceeds 450l



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“Research and development of a highly automated and safe streamlined process for increased Lithium-ion battery repurposing and recycling”

Issues

- 2040 = 9Mtons/year of LIBs waste
- **Excessive energy costs and consumption** for dismantling and battery diagnostics
- **Wide variety** of battery types

Objectives

Validation of two circular schemes:
Second life for applications in **domestic and industrial energy storage**

- Fast battery diagnostics based on **Electronic Noise Analysis**
- **Robotic** module dismantling system
- **Adaptability and reconfigurability** of the system
- Innovative labelling for **DBP** and **Ecolabel**

Solutions

- Second-life battery value chain
- Automatic dismantling system
- Digital Battery Passport

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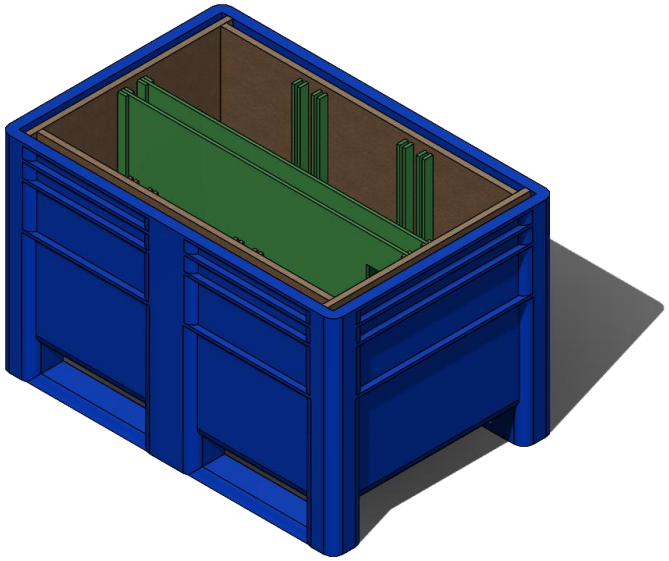
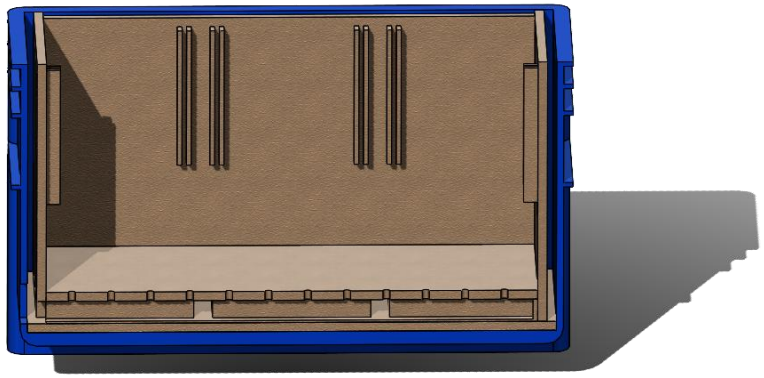
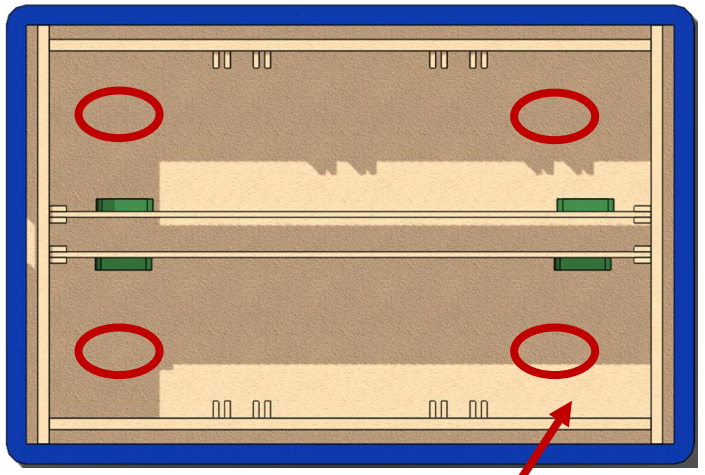
Containers for batteries

UPV – Passive systems





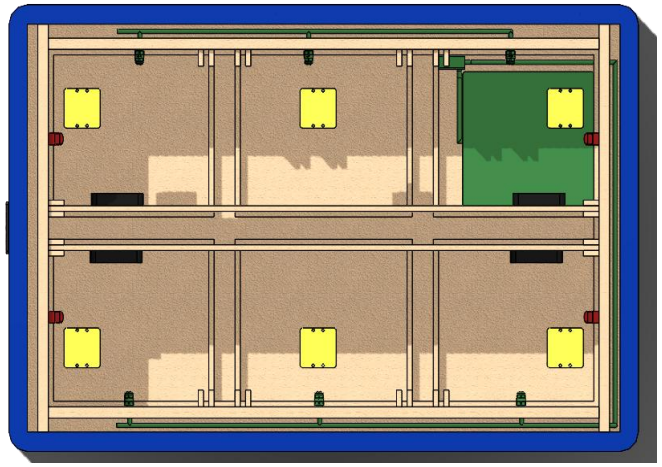


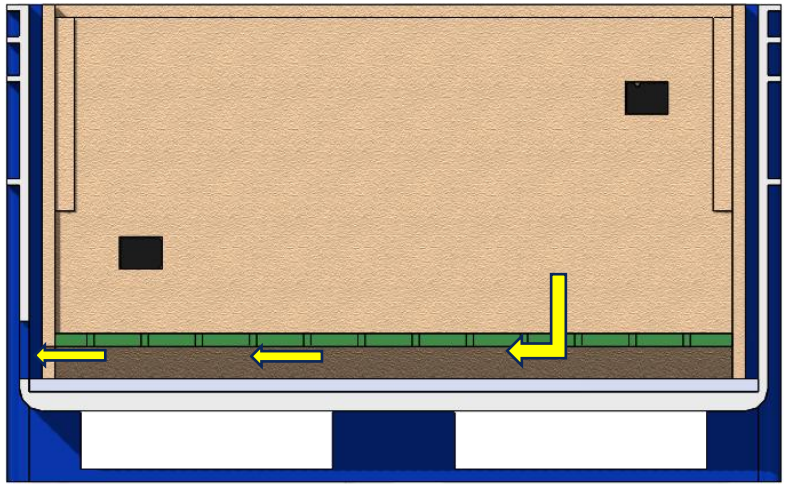
- Contain the battery and the electrical parts: **Standard HDPE box pallet**
- Provide thermal insulation to slow down propagation: **fire-resistant panels and intumescent seals**
- Absorb and neutralize thermal energy and gases: **inert materials or PCM**
- Release pressure in a controlled manner to prevent explosions: **relief pressure valves**

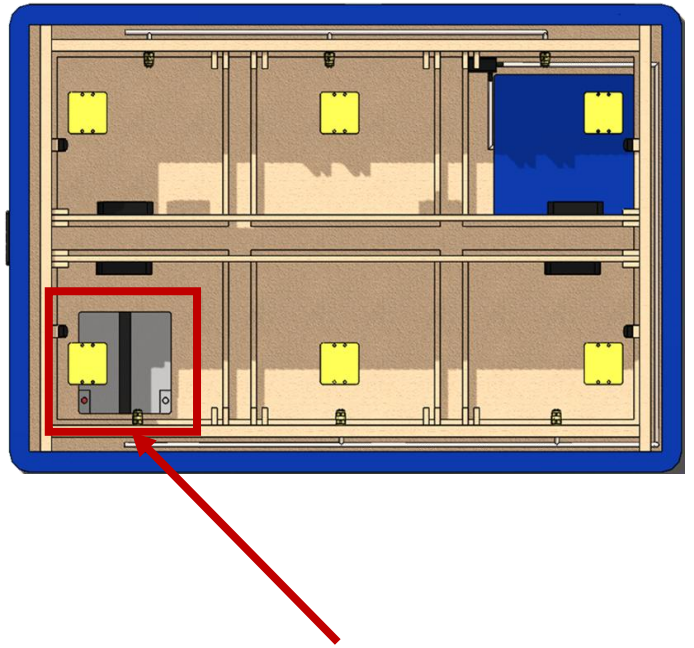
Bag of silicon dioxide microspheres to work as "thermal nests"

Containers for batteries

UPV – Active systems







- Early detection:
  - **Sensors** (temperature, gas, smoke, pressure)
  - **Thermographic cameras**
- Immediate action (suppression):
  - **Water spray cooling**
  - **Gas extraction system**
- Coordinate intelligent response with **remote alarms.**

Containers for batteries

How to integrate them in treatment plants?

Final volume = 0.34 m^3
Estimated cost = 1500 €
Aprox weight = 135 Kg

The main desired properties for a new container are:

- **Early detection** system and **alerting** to avoid escalation
- **Complete containment** of the reaction, ensuring that external objects are not affected
- **Delaying thermal runaway**, to have time to move the container in a safe place

Possible issues:

- Presence of the power supply battery
- Cost and weight

Digital Battery Passport

Dataset

- Digital Battery Passport is a digital document that collects key information about a battery throughout its entire life cycle
- It improves **transparency** on the battery's origin, composition, performance, sustainability, and condition.
- It supports **traceability**, reuse, recycling, and regulatory compliance, helping manage batteries more sustainably

Field	Multiple choice
Battery ID	
Model	
Production Date (mm/yyyy)	
Application/use	❑ EV ❑ LEV ❑ Stationary Storage ❑ Small electronics ❑ Other
Battery format	❑ Pack ❑ Module ❑ Cell
Type of cell	❑ Cylindrical ❑ Prysmatic ❑ Pouch ❑ Blade ❑ Other
Battery chemistry	❑ Lithium-ion ❑ Ni-MH ❑ NiCd ❑ Solid state ❑ Alcaline ❑ Sodium-ion ❑ Lead acid ❑ Other
Manufacturer	
Dimensions	
Weight	
Value (Euros)	

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The University of Nottingham

Is it possible to obtain all this information?

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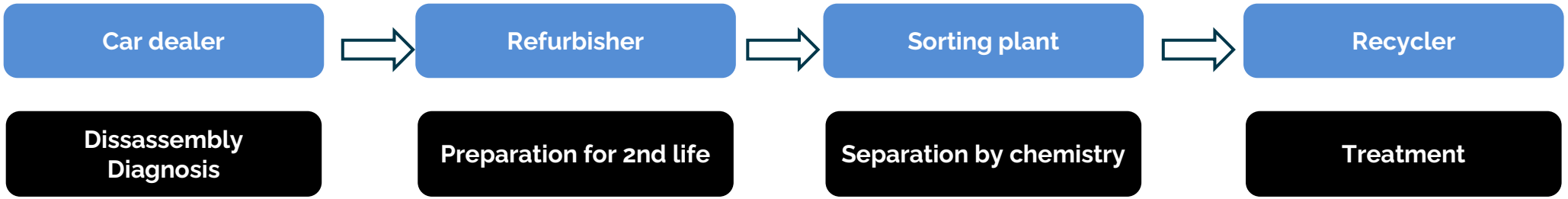
Digital Battery Passport

Pilot Project involving a Volkswagen dealership



Objectives of the Pilot Project:

- Verify data availability
- Evaluate battery traceability
- Validate the data collection process along the end-of-life value chain
- Test the application usability
- Identify process gaps
- Assess scalability

Digital Battery Passport

Pilot Project involving a Volkswagen dealership

Phase 1:

- Fill in the Excel database for each battery sent for recycling
- Assign a unique ID code to each battery to ensure traceability
- Notify Erion when the battery is collected and transported
- Track the final destination facility

Phase 2:

- Test the DBP platform on batteries sent for recycling
- Evaluate both data-entry fields and overall user experience
- Assess feasibility for future DBP implementation

Diagnosis

New Battery Diagnostic Method

- Based on **Electric Noise Analysis** (ENA) to assess Li-ion cell condition
- Uses **experimental battery data** to extract relevant diagnostic information
- Supports the estimation of key battery parameters, such as **State of Health** (SOH) and **State of Charge** (SOC)
- Aims to enable **faster** and **more reliable battery assessment** for second-life applications

There are no standardized procedures for battery diagnosis yet

Conclusions

Take-home messages

- End-of-life Li-ion batteries require an **integrated value chain approach**, combining collection, diagnosis, transport, second-life assessment and recycling.
- **Diagnosis** is essential to decide between reuse, second life or recycling, but **no standardized procedure** is currently available
- **Safety containers** are fundamental to reduce risks during storage and transport
- **Digital Battery Passport** supports data collection, compliance and improves traceability
- **Pilot projects** help validate technologies before large-scale implementation

Thank you for your attention!

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