Fraunhofer Research Institution for Materials Recycling and Resource Strategies IWKS

폐배터리 재활용 기술 개발 현황

Songhak Yoon

6 December 2023

2023년 재외한인공학자 네트워킹 신기술 세미나

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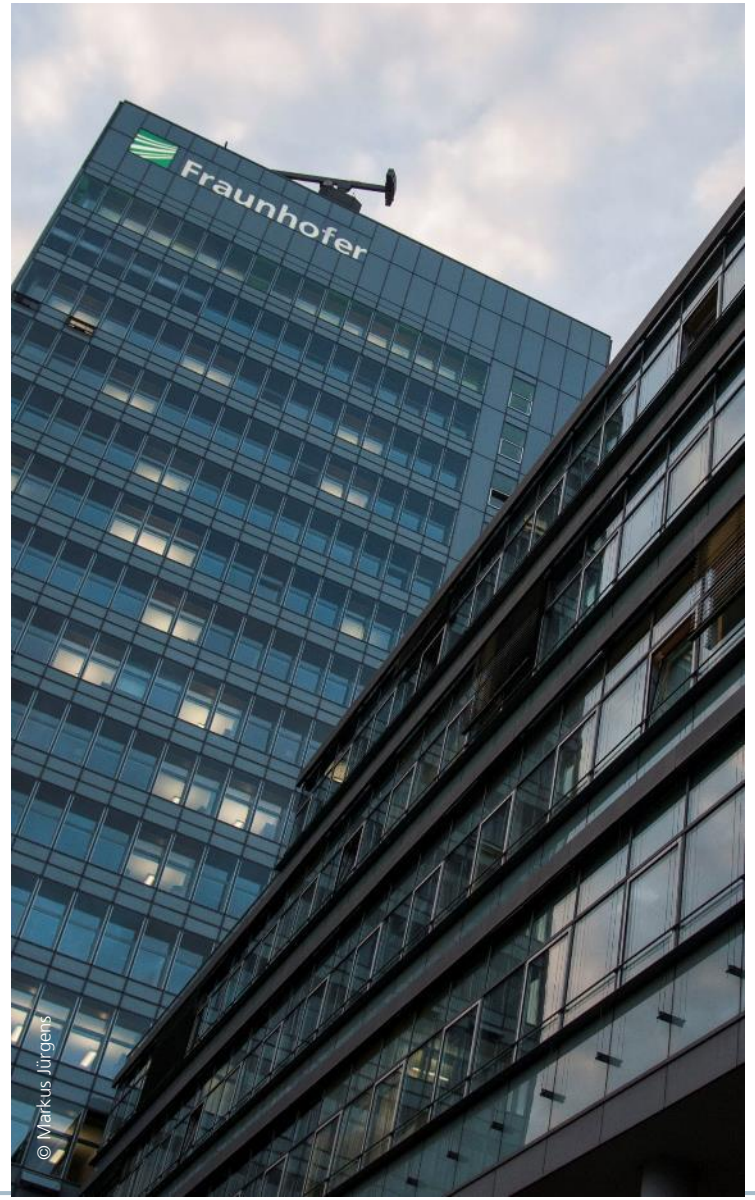
Fraunhofer-Gesellschaft

The leading applied research organization

The Fraunhofer-Gesellschaft, based in Germany, is **the world's leading applied research organization**. Prioritizing key future-relevant technologies and **commercializing its findings in business and industry**, it plays a major role in the innovation process.

A trailblazer and trendsetter in innovative developments and research excellence, it is helping shape our society and our future. Founded in 1949, the Fraunhofer-Gesellschaft currently operates **76 institutes** and research units throughout Germany.

Over 30,000 employees, predominantly scientists and engineers, work with an annual research budget of 2.9 billion euros, 2.5 billion euros of this being designated as contract research. Roughly two-thirds of that sum come from industry contracts and publicly-funded research projects. Approximately **one-third of it is base funding contributed by the German federal and state governments**.



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Fraunhofer-Gesellschaft in Germany

Main locations
Secondary locations

Founded in 1949, the organization currently operates 76 institutes and research facilities in Germany.

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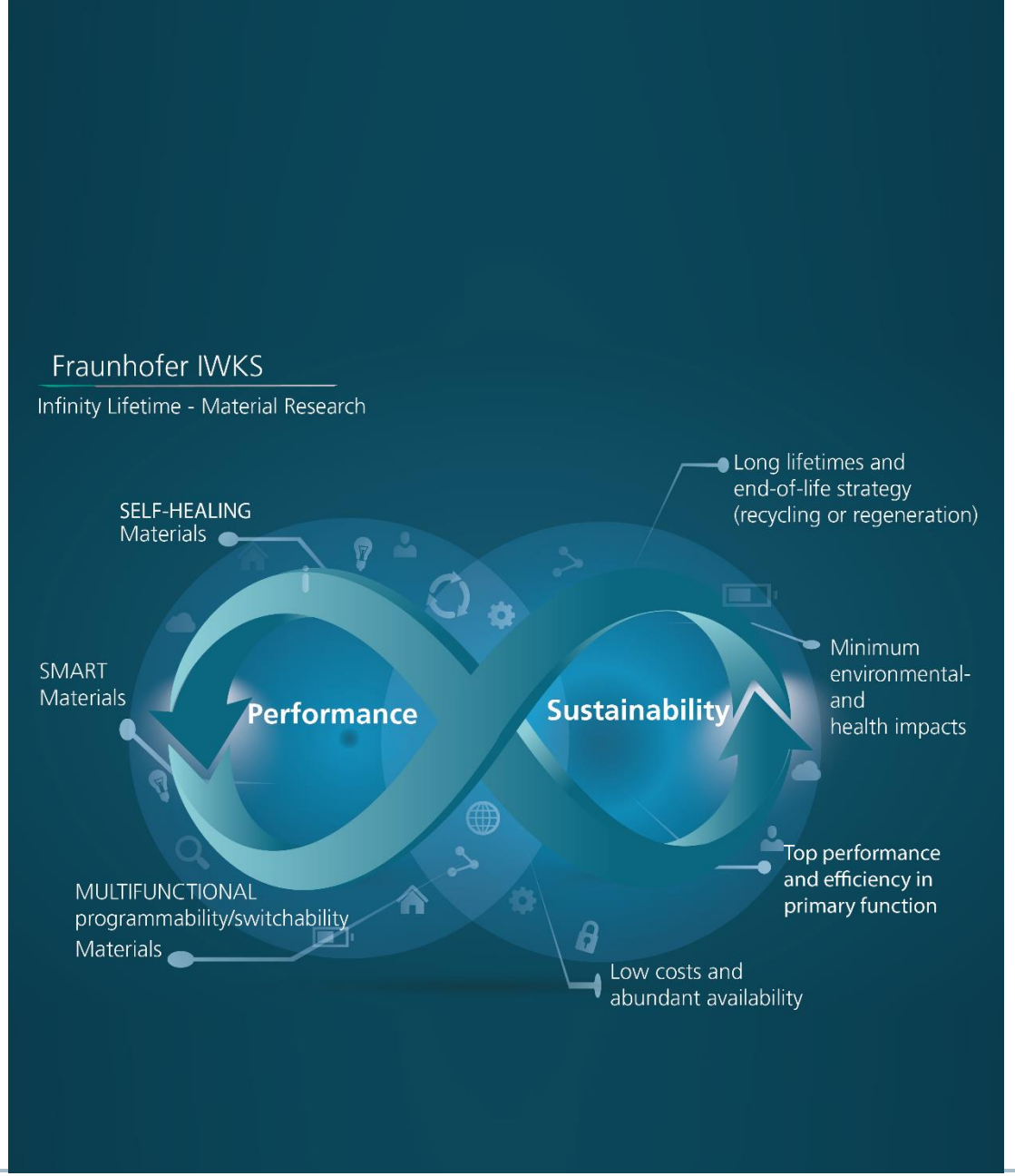
Researach at the Fraunhofer IWKS

Materials for the Circular Economy

We develop new materials and technologies based on material science for a sustainable, waste-free circular economy.

Our research includes

- energy-efficient recovery of materials (recyclates) as sustainable precursors for production,
- intelligent regeneration of future-oriented materials with regard to longevity of products.



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LIB Recycling overview at IWKS

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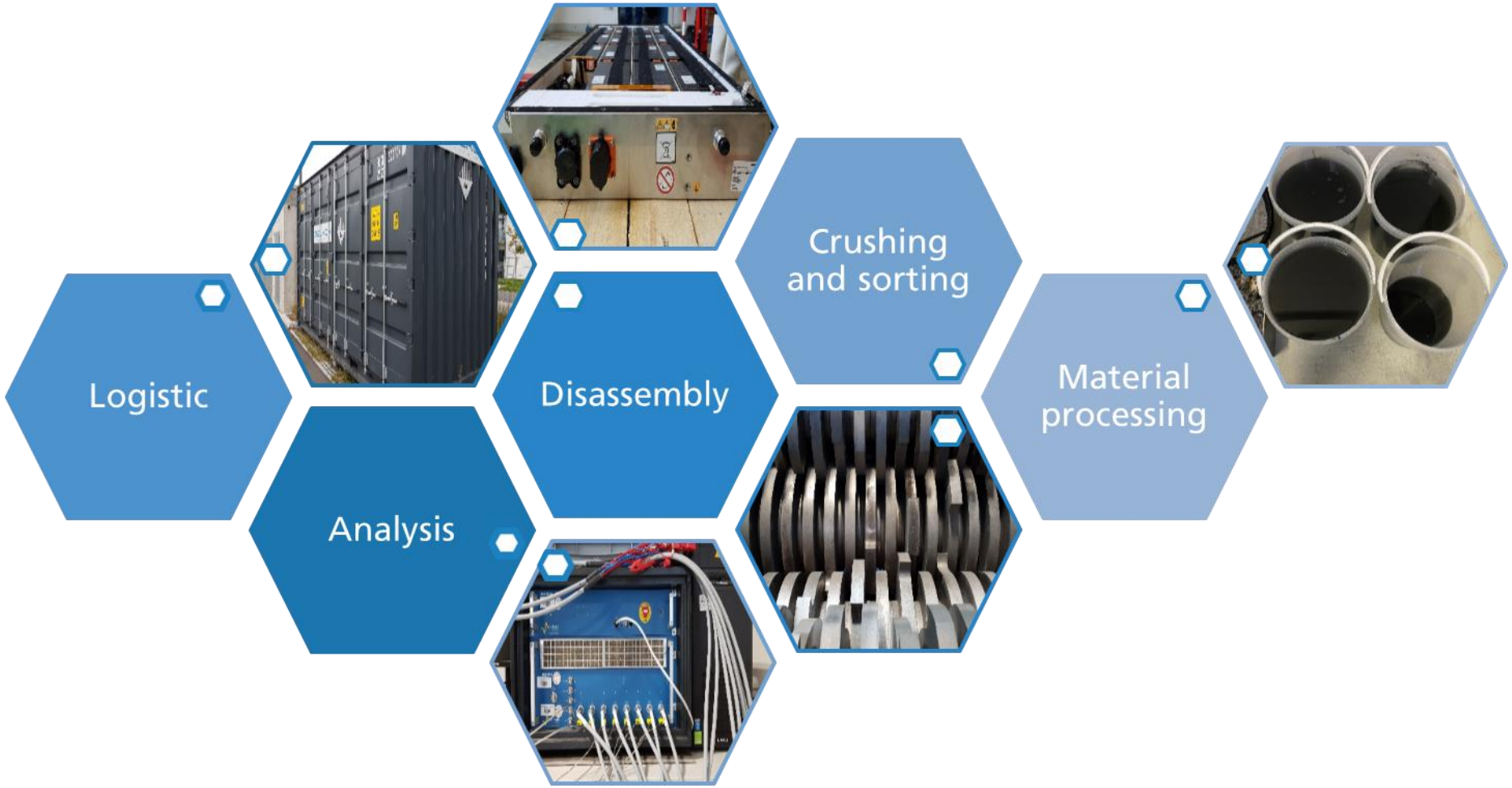

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Battery Recycling Paves the Way to Sustainability

Scientific Focus

- Innovative separation processes for complex composites
- Processes for the enrichment of critical metals
- Preparation and development of functional materials with low criticality
- Material analysis and in-process analysis for the development of highly efficient recycling processes

Battery Recycling through innovative processes

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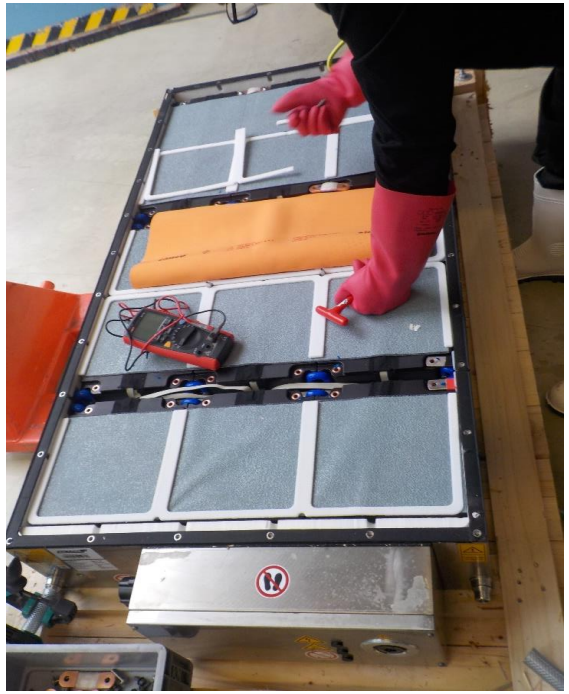
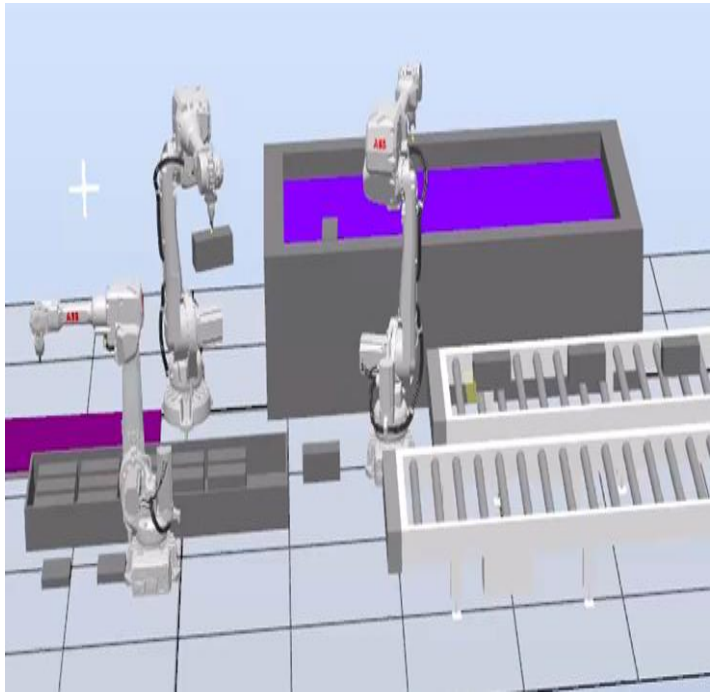
Various disassembly approaches



➢ Manual

➢ Semi-automatic



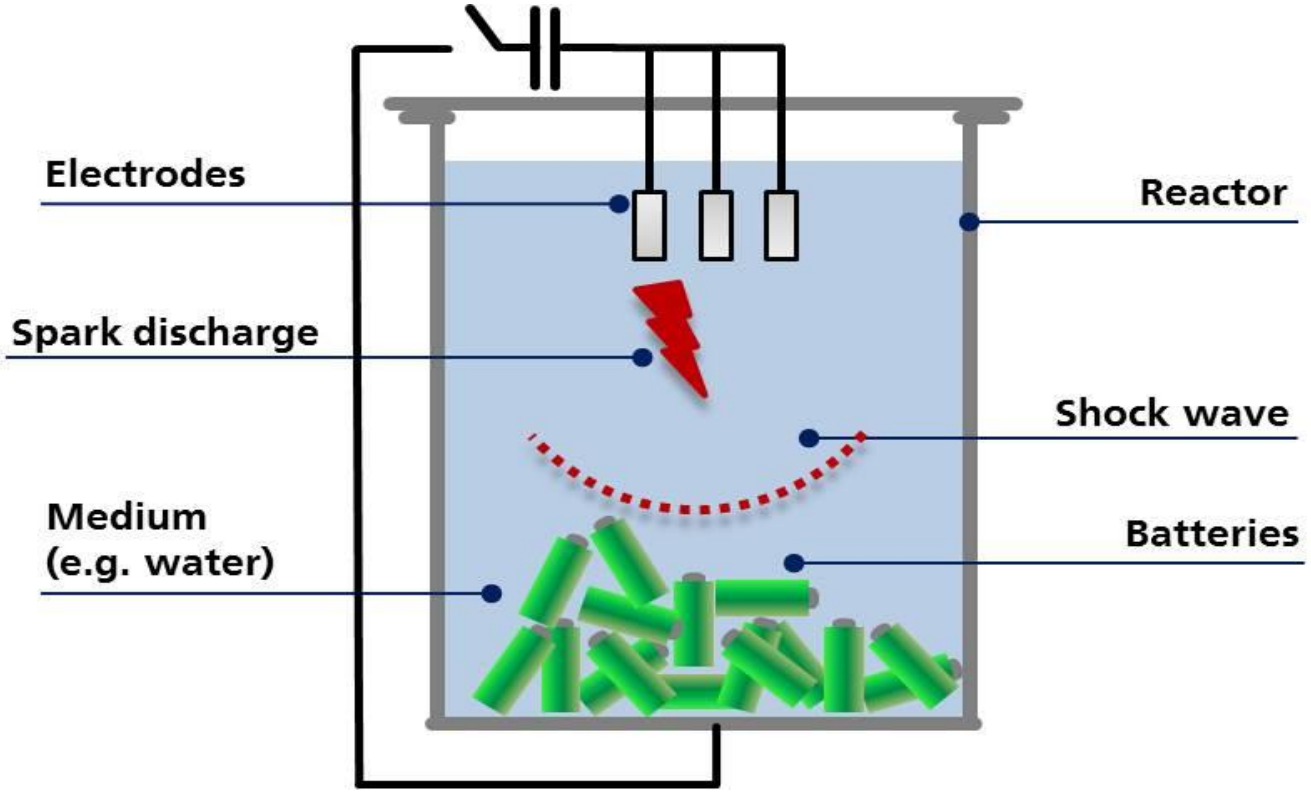
➢ Fully automated

Precrushing – Four-shaft shredder

- Robust initial pretreatment for seperation of housing parts

Electrohydraulic Fragmentation (EHF)

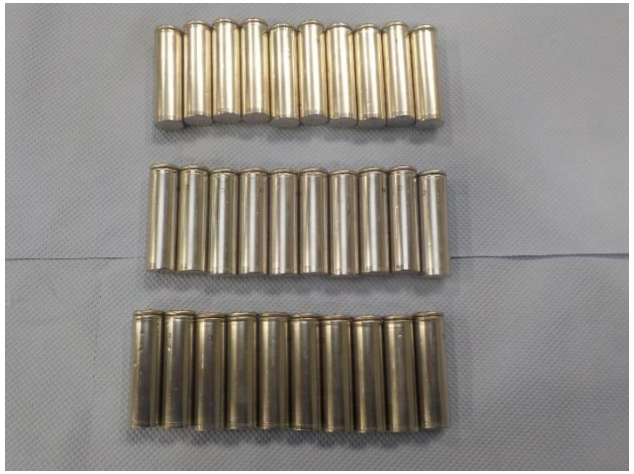
The EHF-Technology: Selective and effective



Breakdown into individual components

Without loss of any components

Elektrohydraulic Fragmentation



Fotos: Fraunhofer IWKS

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Elektrohydraulic Fragmentation

- One batch - 30 cylindrical cells

  5500 pulses until complete disassembly (on average)

  0,7 - 0,8 kg Black mass yield (wet) per experiment

  Stability of the cells increases according to the following cell shape order: pouch - prismatic - round cells

Fotos: Fraunhofer IWKS

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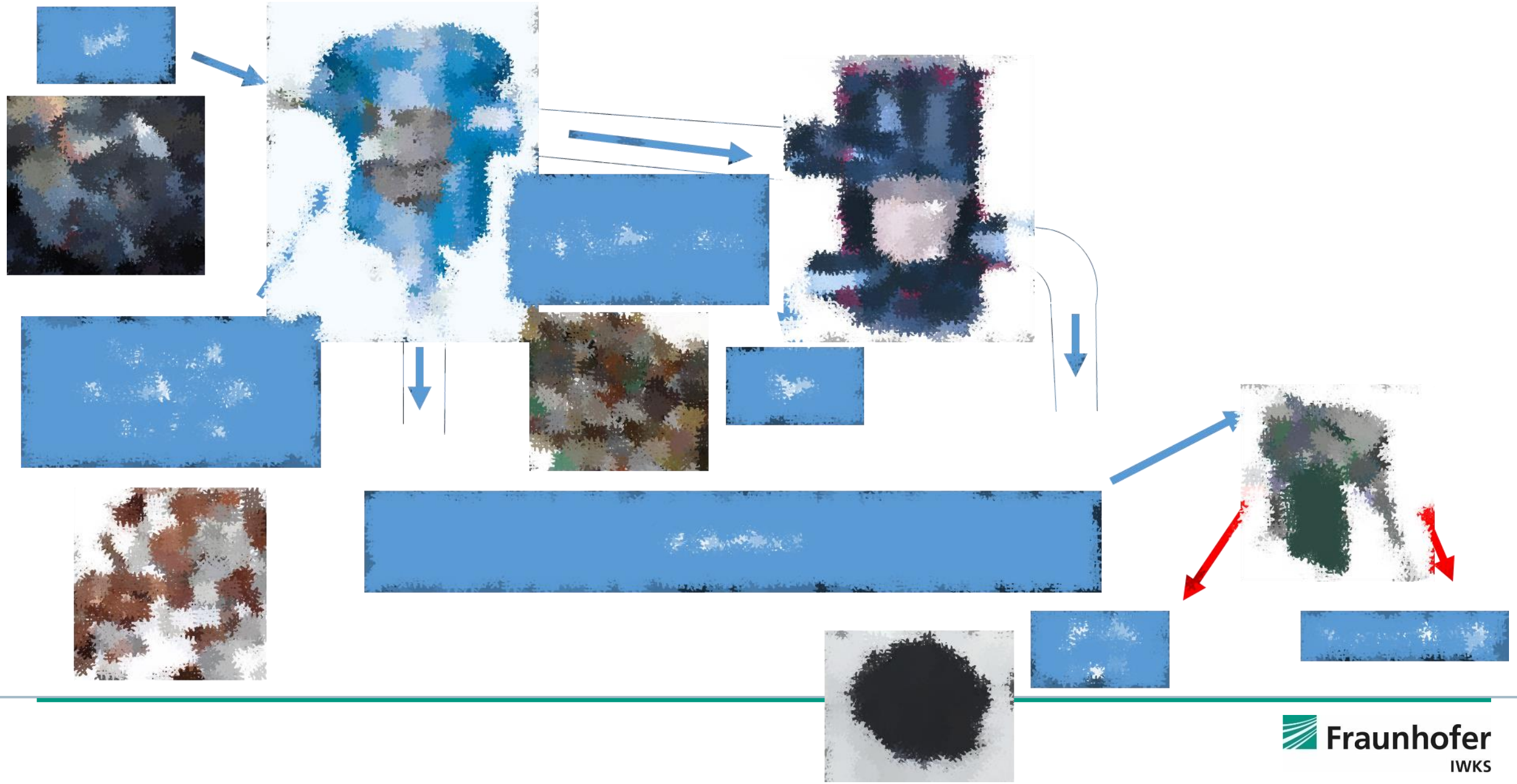
SuSi (Skimmen und Sieben)



Equipment & processes

Precursor
for Benchmarking

Inert preparation

(Electro)chemical processing

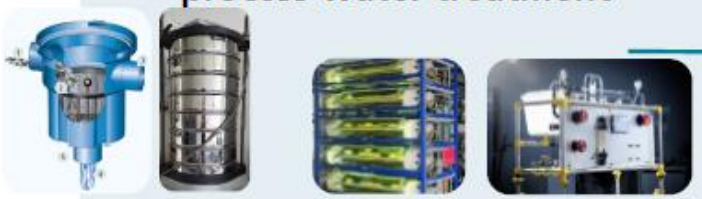
raw material → Material Manufacturing → cell manufacture → battery manufacture → use → return logistics → dismantling → pre-treatment (e.g. thermal) → crushing or pyrometallurgy → sorting/ separation → hydro-metallurgy → raw material

Production of test cells

Theoretical basics

LCA, modelling, programming, constructions, research

Wet + dry sorting, process water treatment



preconditioning

Safe storage and transport

Discharge & analytics

Automatisation

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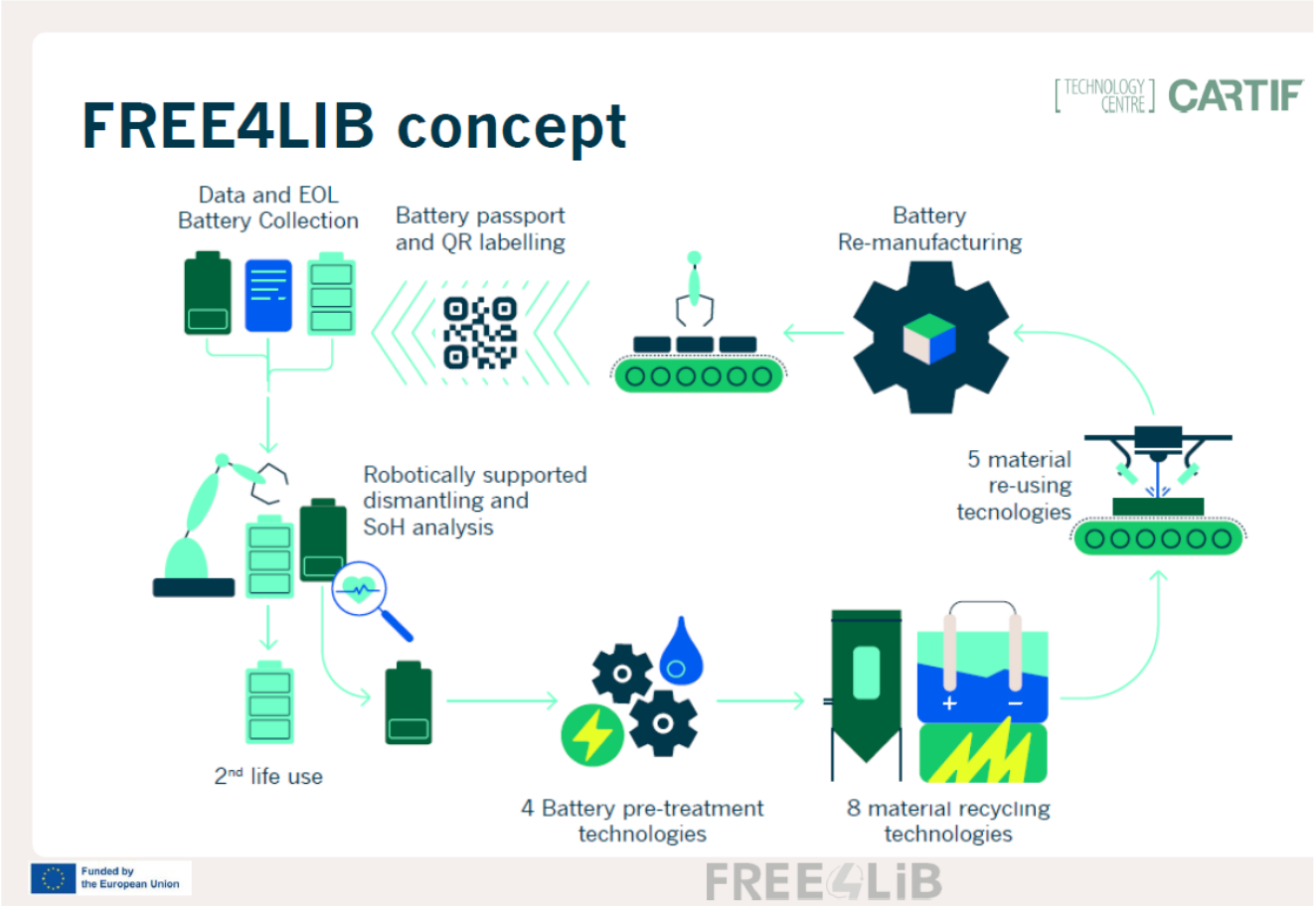

Feasible Recovery of critical raw materials through a new circular Ecosystem FOR a Li-Ion Battery cross-value chain in Europe

Making it easier to recycle and remanufacture end-of-life lithium-ion batteries. The transport sector is responsible for around one quarter of Europe's greenhouse gas emissions. Electric vehicles can contribute significantly to the decarbonisation of future road transport, but lithium-ion batteries (LIBs) remain an obstacle: they are not green enough to sufficiently reduce mobility footprints.

About

Who we are


BATRAW
The Project
Objectives
News
Events
Deliverables
Partners
Newsletter
Materials
BATRAW PROJECT
RECOVERY OF CRITICAL RAW MATERIALS
FROM ELECTRIC VEHICLE BATTERIES
A joint effort of 18 partners from 7 different countries
2022-2026
BATRAW PROJECT
FUNDING
€13,212,811
OBJECTIVE
RECYCLING OF BATTERIES

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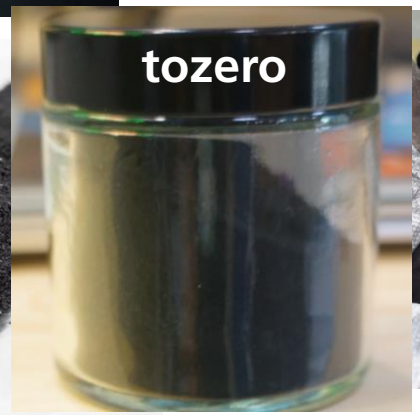
Black mass - a key for the closed-loop battery recycling



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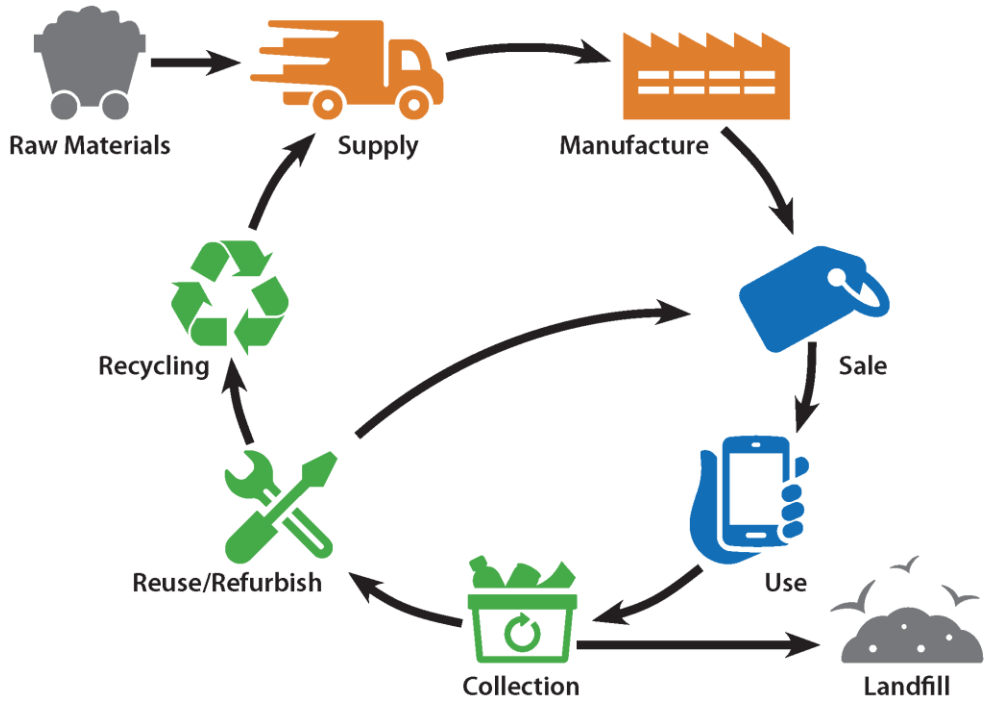
Closed-loop battery recycling



https://www.epa.gov/recycle/used-lithium-ion-batteries

- Process that involves manufacturing batteries from raw materials, using them in vehicles or other devices, and then recycling them into new materials for future use.

- Recycling LIBs is an expensive investment, requiring a complex and energy-intensive process to recover and purify valuable materials.
- the different sectors of the economy need to become more interdependent → new forms of collaborative models among companies, including novel business models
- Investments in such cooperation are relation-specific, i.e., their returns will depend on the continuation of the relationships. → therefore making long-term commitment difficult, rather joint-venture in LIB recycling

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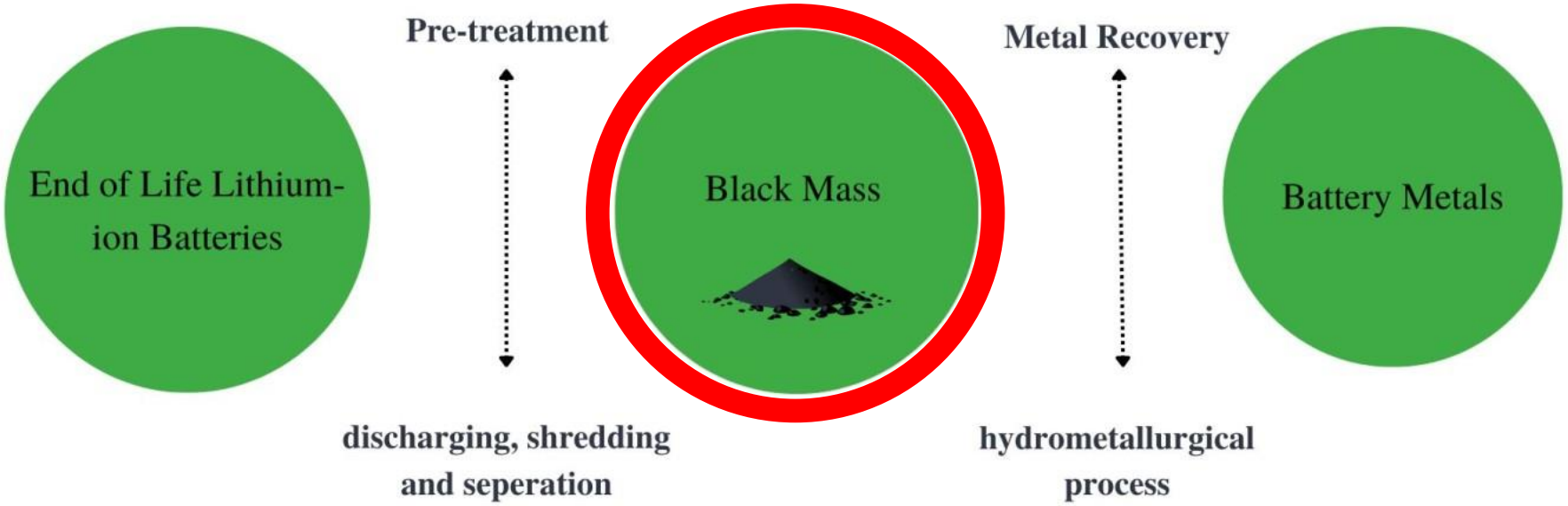
Towards the realization of closed loop LIB recycling



There is a gap between Black mass production and Battery metal recovery

The gap needs to be narrowed. By how ?

https://econilibattery.com/embracing-sustainable-battery-recycling-with-hydrometallurgical-process-%f0%9f%94%8b/

Contaminant Identification matters

Contaminant Identification Refines Recycling for Lithium-Ion Batteries

New Approach Aims To Improve Purity of Recycled Battery Materials

Feb. 14, 2022 | By Rebecca Martineau | Contact media relations

- **To pinpoint these impurities**, NREL and ANL combined electrochemical analysis with isothermal microcalorimetry to identify characteristic "fingerprints" for each metallic contaminant, including iron, aluminum, copper, silicon, and magnesium. This synergistic approach allows researchers to confirm the presence of contaminants and assess the impact of each metallic impurity on the overall performance of the recycled electrodes.

https://www.nrel.gov/news/program/2022/contaminant-identification-refnes-recycling-for-li-ion-batteries.html

BLOGS

Mastering Impurity Control: The Key to Sustainable Lithium-Ion Battery Recycling♻️

August 4, 2023 / by Nathalie Fraga

INTRODUCTION

Unlocking the secrets of sustainable lithium-ion battery recycling holds the promise of a greener future. As the demand for electric vehicles and renewable energy solutions skyrockets, the extraction of valuable materials from spent batteries becomes paramount. Amidst this electrifying pursuit, impurity control emerges as the ultimate game-changer during the black powder production stage – the first step in treating scrap lithium-ion batteries before delving into the transformative hydrometallurgy process for lithium extraction.

Understanding the standard content

The tantalizing journey begins with a captivating challenge – maintaining specific impurity levels in the black powder. Concealing a treasure trove of Lithium compounds, Cobalt, Nickel, and more, the black powder's purity holds the key to unlocking the full potential of recycling. The standards are clear:

Aluminum (Al) & Copper (Cu) – below 2%
Iron (Fe) – below 0.03%

Recycling refineries step into a new era of environmental responsibility and technological excellence. Witness the ascent of these pioneers as they harness the power of impurity control to sculpt a future of cleaner, brighter, and more sustainable energy.

https://econilibattery.com/mastering-impurity-control-the-key-to-sustainable-lithium-ion-battery-recycling/

Key points to remember

Black mass value will increase as recycling tech improves

However, as for now

Black mass may not become a commodity as its composition and quality varies too much.

Nevertheless,

We should see value where others see waste !

Mines are local, spent LIBs are everywhere

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Direct Recycling & Direct Regeneration

Direct recycling

Mechanochemistry with molten salt

Thermal treatment /

Regenerated cathode materials

Li-ion batteries

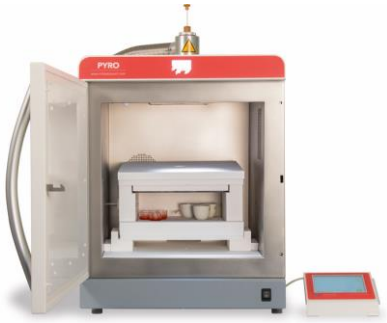
Scrap / Black mass

Closed-loop recycling of Li-ion cathode materials

Green hydrometallurgical recycling route

Spent Li-ion battery cathode

\+ Li, Mn, Ni sources



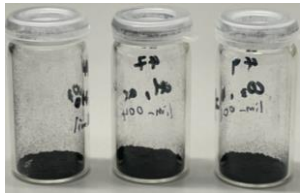
Dissolution / gelation in deep eutectic solvent

- Microwave-assisted heating

Calcination

- 2-stage heat treatment
- Remove solvent components

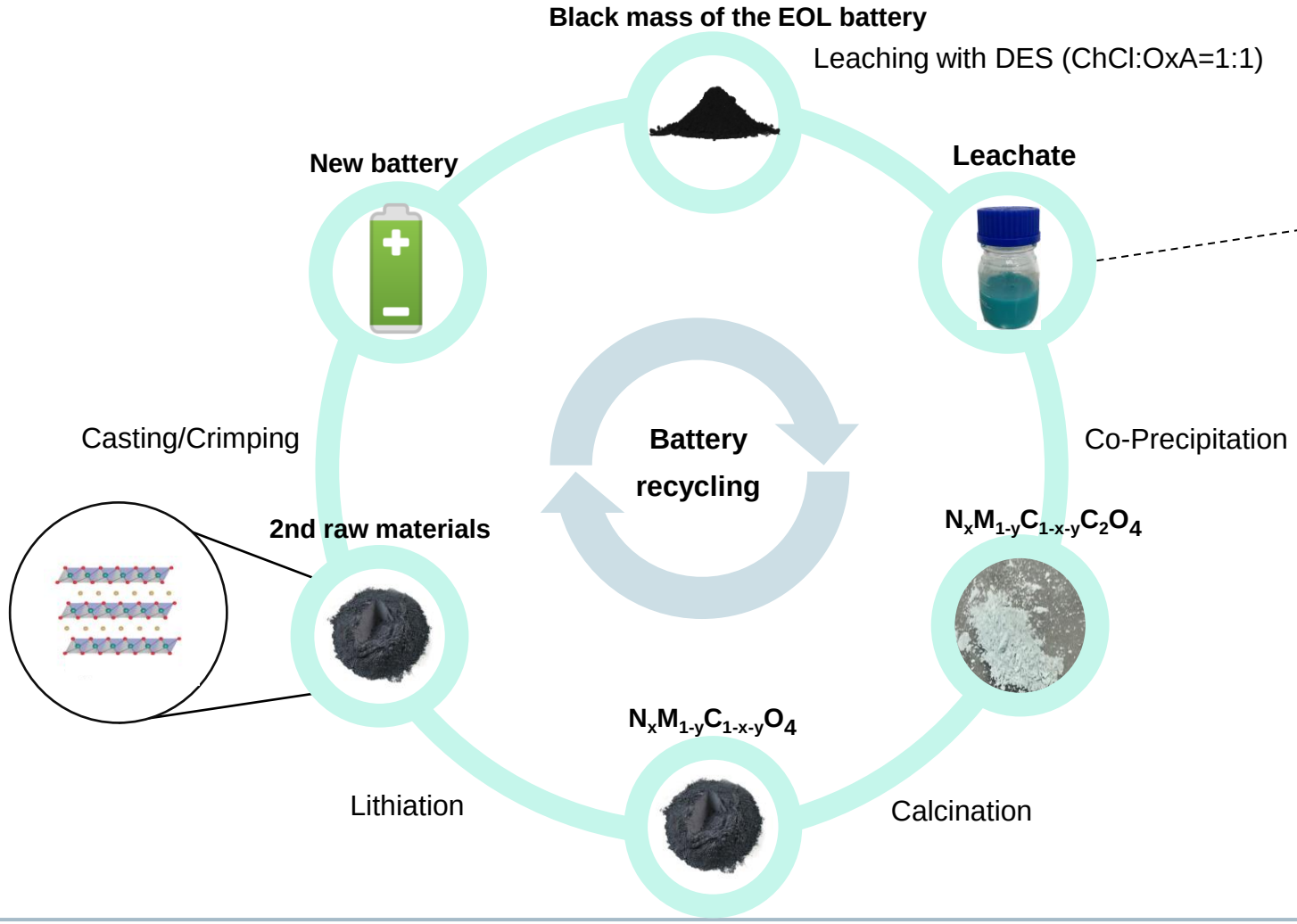
Regenerated / upcycled cathode material



Li-ion battery cell fabrication

Green Hydrometallurgical Recycling Route

A closed loop of battery recycling



- Kona622 Black mass
- Bosch811 Black mass

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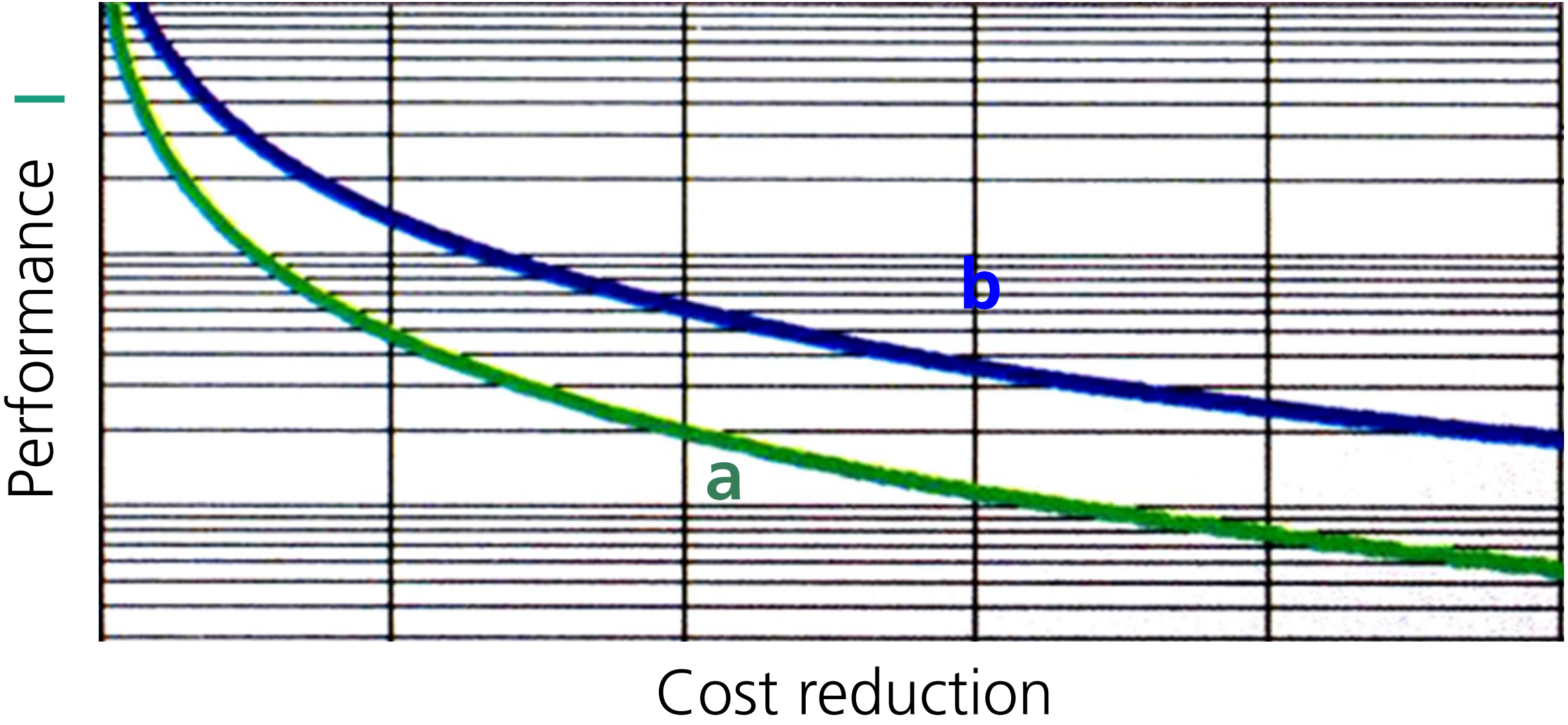
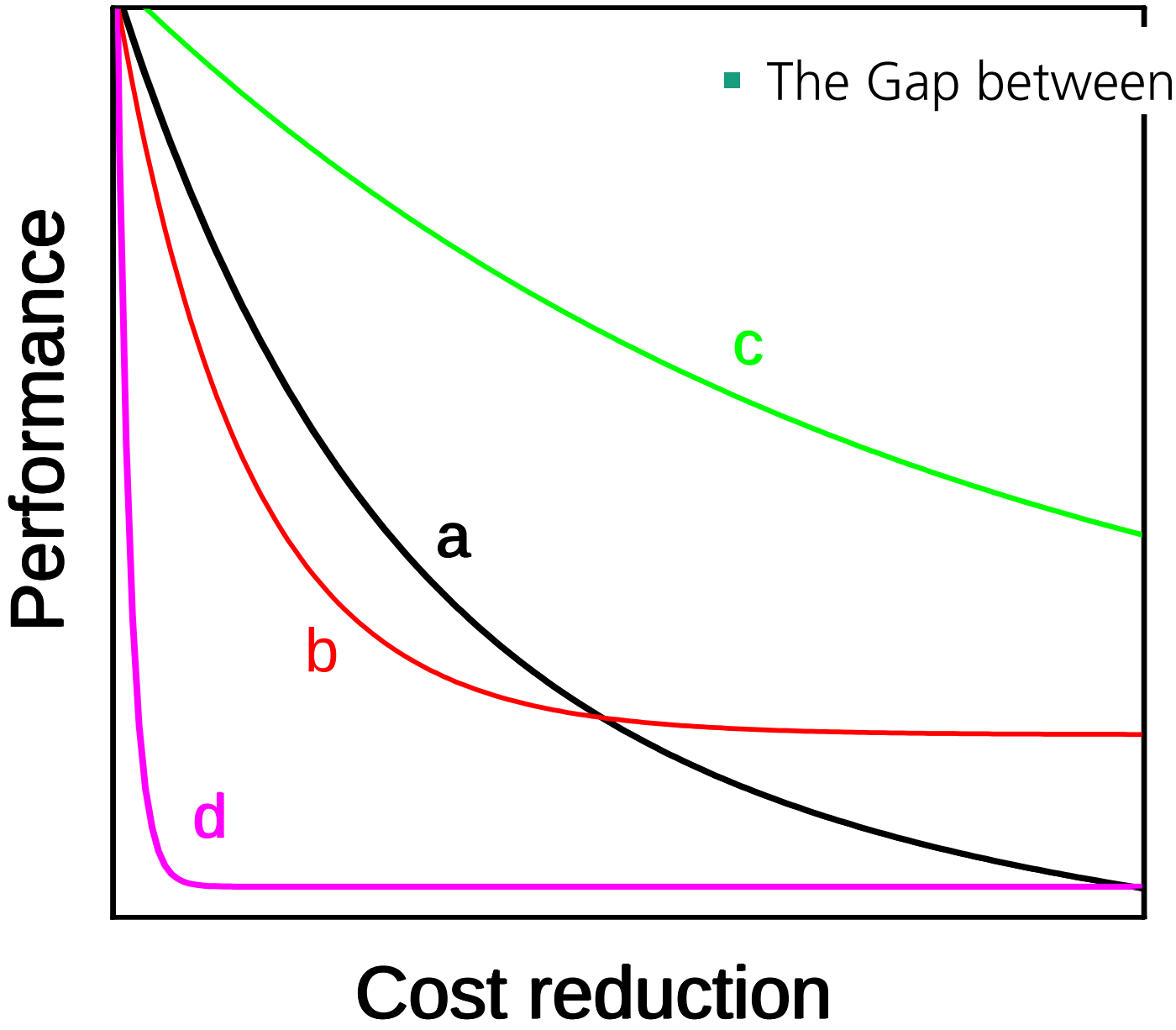

Performance
b
a
Cost reduction

- The Gap between **a** and **b** …



Global climate strike

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Global climate strike
at Darmstadt,15. 09. 2023

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SYSTEM
CHANGE
NOT
CLIMATE
CHANGE

“Agreement is not enough

unless there is a high-level commitment.”

“Policy and innovation go hand in hand.

Everything is interconnected.”

— Ryan Panchadsaram at ClimateTech 2022

가능한 미래 **likely or possible future** 와

바람직한 미래 **desirable or preferable future**

사이의 간극을 줄이려는 노력.

따라서 가능성 여부와 상관없이 모든 제안을 심도있게 검토할 필요가 있다.

오늘 저의 배터리 재활용 발표를 통해

1) 어떻게 **(how)** 블랙 매스를 만들고

2) 어떻게 **(how)** 블랙 매스로 부터 가치있는 재료를 만드는지

더 중요하게는

왜**(why?)**블랙 매스를 만들어야 하는지

왜 **(why?)** 블랙 매스가 지속가능한 순환 경제에 필수 요소인지

심도있게 의논하는 계기가 되기를 소망합니다.

Thank you for your interest!

Dr. Songhak Yoon

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