Evaluation of Material Recovery Route: Target Reached

Assessment of FuLIBatteR Recycling Pathways for Black Masses Derived from Lithium-ion Batteries to Recover Critical Raw Materials and Valuable Elements

One of the final milestones of the FuLIBatteR project, outlined in Deliverable 1.5, “Publication on Recycling Efficiency Improvements by New Developed Processes”, focused on identifying and validating effective methods for recovering black mass from end-of-life lithium-ion batteries. Over the past months, project partners have concentrated on collecting and analyzing data from a range of experiments with different battery cathode chemistries to investigate the different recovery processes under research in COMET Module FuLIBatteR. By comparing the performance of these processes, the partners aimed to investigate and determine the most efficient pathway for the recovery and purification of critical raw materials (CRMs). The investigation provides a systematic experimental evaluation of froth flotation, pyrometallurgical, hydrometallurgical, and bio-hydrometallurgical routes, assessing their potential for comprehensive material recovery.

As with most LIB recycling approaches, the process begins with the collection, sorting, and mechanical treatment of battery waste to separate black mass from other battery components. Building on this foundation, FuLIBatteR developed an integrated recycling concept that combines process engineering, metallurgy, and biotechnology to maximize resource circularity. An outline of the processes under study is given in Figure 1.

The proposed recycling framework incorporates a series of complementary process steps, including battery deactivation, flotation, magnetic separation, thermal pre-treatment, (bio-)leaching, refining, and metal recovery. Several of these technologies demonstrated strong performance, enabling the recovery of high-purity fractions of valuable materials.

The results highlight promising recycling efficiencies and successful recovery of graphite and key battery metals such as lithium, cobalt, nickel, and manganese. These findings demonstrate the potential of the FuLIBatteR approach to support current and future EU recycling targets while contributing to a more sustainable and resilient supply of CRMs.

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Can a single recycling approach effectively recover CRMs across the full range of lithium-ion battery chemistries?

By comparatively evaluating the recycling techniques, this investigation clarifies the strengths and limitations of each method and highlights their potential for effective CRM recovery from LIB waste. The investigation outlines the experimental investigations conducted on selected black mass streams, including specific chemistries of nickel–manganese–cobalt oxide (NMC) and lithium–iron–phosphate (LFP) representing the most widely utilized cathode chemistries in contemporary LIBs, and additional material fractions such as HL (composed of NMC and LCO cathodes), in accordance with the defined research scope and process compatibility considerations.

Owing to differences in chemical composition and metallurgical behavior, not all recycling routes were applicable to every material type. This selective, yet systematic approach, enables a realistic evaluation of interactions between processes and materials while maintaining alignment with sustainability and circular economy principles, thereby establishing a focused and technically sound basis for optimizing CRM recovery strategies. In other words, the work sees the future not as a single universal recycling process, but as an integrated system:

- Mechanical pretreatment to separate components
- Sorting by chemistry where feasible
- Different downstream recovery routes tailored to the battery type and target materials

So, while a single recycling approach can technically process many lithium-ion batteries, no existing approach recovers CRMs with equally high efficiency, purity, and economic value across the entire spectrum of lithium-ion battery chemistries. Flexible, chemistry-aware recycling systems are generally considered more effective.

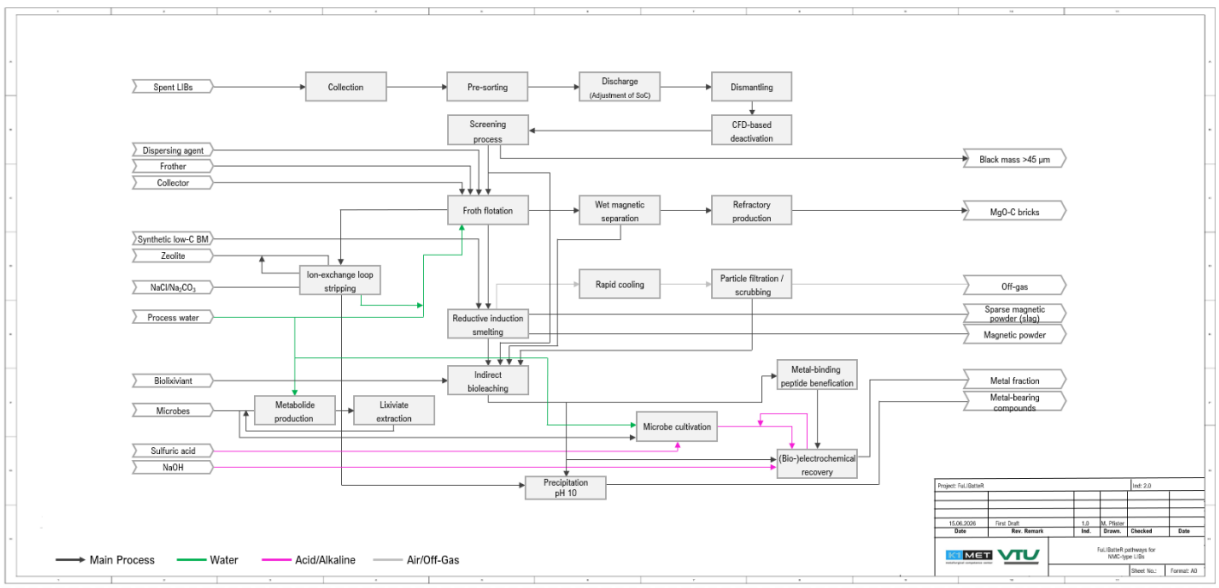

Abbildung 1: Schematic overview of FuLIBatteR pathways for recycling critical raw materials.

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Dissemination

The FuLIBatteR COMET module was presented during the 15th Scientific Exchange Day (SED) of K1-MET GmbH at voestalpine Stahlwelt in Linz on 9 April 2026. This event served as a platform for sharing knowledge, ideas and innovations within the K1-MET partner network including researchers, industry partners and stakeholders to discuss current developments and future perspectives in metallurgical research.

Figure 2: Bettina Rutrecht presenting FuLIBatteR during the Scientific Exchange Day.

On 18 May 2026, Rebeka Frueholz presented FuLIBatteR at the event „Raus aus der Nebelzone: Kreislaufwirtschaft – Welt ohne Muell.

Figure 3: Rebeka Frueholz presenting FuLIBatteR at the event „Raus aus der Nebelzone: Kreislaufwirtschaft– Welt ohne Muell.

On 11 June 2026, the Female Tech Summit took place at the Ursulinenhof in Linz with the focus on women in IT, technology, research and innovation. Together with the UAR Innovation Network, COMET Module FuLIBatteR was presented at a dedicated exhibition stand.


Figure 4: photo left: Anna Sieber (4th from right) and photo right: Rebeka Frueholz (5th from right) at Female Tech Summit.

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For more information about the FuLIBatteR project and its progress, please visit LinkedIn and the K1-MET-Website.

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