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Life cycle assessment of an innovative process assisted by pressurized CO₂ for the direct recycling of lithium-ion battery positive electrode production scraps

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The battery market continues to expand due to the electrification of mobility, resulting in a rising need for lithium-ion batteries (LIB) and subsequently their recycling. As this demand rises, the amount of waste generated during the manufacturing process, including production scraps, is also expected to increase. These scraps can account for up to 30 wt.% and represent an initial and accessible target for recycling within a closed loop [1]. In addition, the European Commission has signed a regulation for battery recycling and e-waste management to improve recycling efficiency, material recovery rates and to ensure a minimum recycled content in new batteries [2].

Currently, the two main recycling processes operating at industrial scale are pyro and hydro-metallurgy. Despite their capabilities in recovering components, these processes have limitations as they require high-energy inputs or excessive use of high concentrated acid solvent, respectively. In the context of recycling electrode production scraps, the current technology seems inappropriate, as the materials are in a pristine state and only partially assembled. To answer this challenge, direct recycling – a promising alternative process that aims to separate the different components of a battery and recycle them independently – seems suitable for retaining the positive electrode material's morphology and functionality. While this method is still at laboratory scale, it has the potential to be environmentally friendlier than other recycling methods.

This presentation aims to assess an innovative LIB direct recycling process using pressurized CO₂ mixed with organic solvents in batch conditions under optimized experimental parameters. The feasibility of this recycling process is demonstrated using LiNi_{0.6}Mn_{0.2}Co_{0.2}O₂ (NMC622) battery electrode production scraps. To further develop the direct recycling of LIB, there is a need for tools to quantify, compare, and analyse the potential environmental impacts of these processes. In this context, Life Cycle Assessment (LCA), a standardized method used in the literature to evaluate the potential impacts and benefits of existing LIB recycling methods, [2,3] is employed in our study. Environmental hotspots are identified with LCA, and subsequently, an eco-design approach is applied to propose experimental solutions aimed at reducing the targeted environmental impacts. A best-case scenario after upscaling can also be modelled to assess the potential benefits of this innovative recycling process in comparison with primary production and other recycling processes.

Preliminary results show that this innovative direct recycling process at the lab scale saves mineral resources, reducing their consumption by up to 70% compared to primary production. Nonetheless, there is an observed increase in the carbon footprint, primarily due to differences in scale modelling. Additionally, two main hotspots are identified: electricity consumption and the use of solvents. To address these hotspots, laboratory-scale optimization can be employed initially. Subsequently, an upscaling methodology can be implemented, with a particular focus on achieving the best-case scenario by increasing the solid/liquid ratio and minimizing electricity consumption.

References

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