LCA of Micromobility NCM batteries: Cradle-to-Grave approach

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LCA analysis of NCM batteries for evaluating environmental impacts of recycling pathways

- Comparative LCA of two end-of-life (EOL) processes:
  - **EOL 1: Pyrometallurgical recycling**
  - **EOL 2: Hydrometallurgical recycling**
- Full life stages of battery analyzed: **raw materials acquisition, manufacturing, distribution, use stage and recycling**
- **Transparent life cycle inventory** to evaluate performance for decision-makers

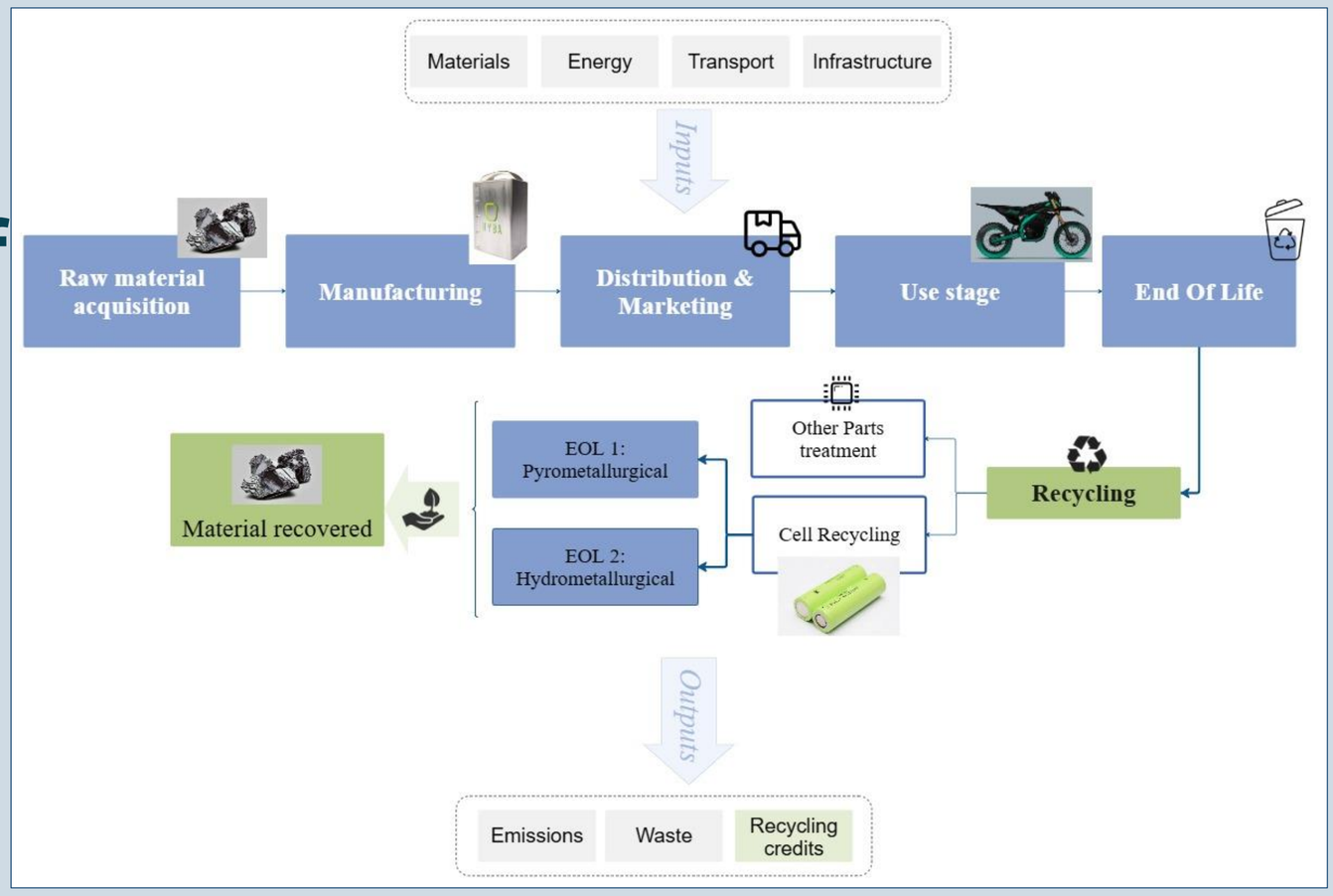

FIG 1: System boundary of the study: cradle-to-grave approach for NCM battery with two EOL recycling scenarios

INTRODUCTION

- Lithium ion batteries are growing in demand and market due to the **electric transition goals**.
- Tail-end emissions reduced but **critical raw materials** (CRM) acquisition create burdens.
- Overall life stages LCA needed to evaluate the total **environmental impacts** on battery value chain.
- **EU Battery regulation** sets goals for CRM recovery, recycling rate and use of recycled content.
- Overall LCA helps decision-makers to imply **eco-design** for battery system to be compliant with the regulations and sustainability goals.

METHODOLOGY

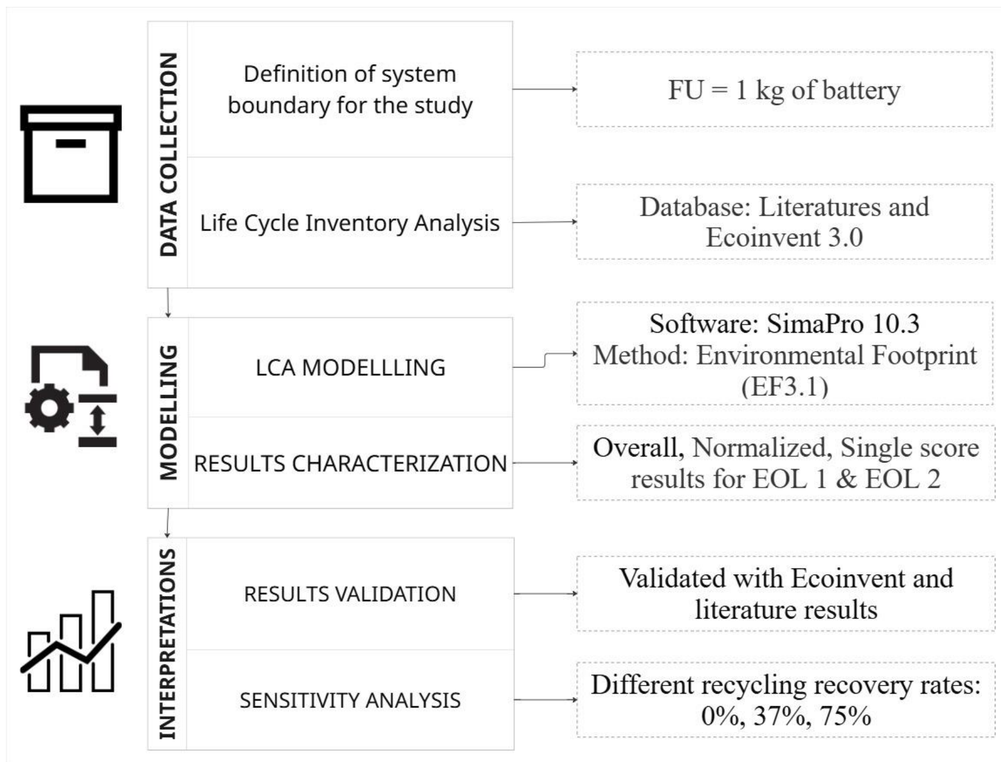

FIG 2: LCA framework for the study based on ISO14040/14044 standards

RESULTS

FIG 3: Weighted impact assessment results with EF 3.1 method for all 16 damage categories

CONCLUSIONS

- Raw materials acquisition stage drives most impact due to **CRM upstream burdens**, while EOL stage shows a significant negative contribution from **avoided burdens** via material recovery.
- Hydrometallurgical process delivers stronger benefit than pyrometallurgical process due to **higher recovery rate** and **broader materials range**.
- While production remains the primary environmental hotspot, **closed-loop material recovery** is indispensable for achieving substantial reduction in life-cycle impacts.

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