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Comparative Life Cycle Assessment of NMC811 and NMC622 Lithium-Ion Batteries: Cradle-to-Gate and Recycling Analysis under South Korean Electricity Mix

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The rapid expansion of electric vehicles has driven demand for lithium-ion batteries particularly nickel-rich chemistries such as NMC811 and NMC622, yet their environmental footprint compared to alternatives remains unclear. This study presents a comparative Life Cycle Assessment (LCA) of NMC811 and NMC622 lithium-ion batteries, focusing on cradle-to-gate impacts and recycling scenarios within the context of the South Korean electricity mix.

Battery production inventories are developed using the BatPaC framework, while environmental impacts are assessed in openLCA with background data sourced from the Ecoinvent database. The assessment adopts a functional unit of 1 kWh of battery capacity and focuses on global warming potential (GWP) as the primary impact indicator. A cradle-to-gate system boundary is applied, encompassing raw material extraction, material processing, and cell manufacturing, with particular emphasis on the supply chains of nickel, cobalt, and lithium. In parallel, recycling is evaluated through a scenario-based approach that incorporates established hydrometallurgical and pyrometallurgical processes, along with their corresponding material recovery efficiencies.

The results indicate that higher nickel content in NMC811 increases upstream environmental impacts, although recycling can partially offset these burdens through material recovery. Accordingly, this study presents a systematic comparison of nickel-rich cathode chemistries and emphasizes the importance of recycling in reducing the life-cycle carbon footprint of lithium-ion batteries under region-specific energy conditions.

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