

Sustainable Battery Recycling and Lifecycle Analysis for Electric Vehicles

Abstract

This research proposal aims to evaluate the sustainability, efficiency, and environmental impact of battery recycling processes in electric vehicles (EVs). With the exponential rise in EV adoption, the accumulation of end-of-life (EoL) batteries poses both an environmental challenge and an opportunity for material recovery. The study will focus on lifecycle assessment (LCA) methodologies to quantify environmental benefits, assess recycling technologies, and propose a circular economy model that minimizes waste and resource depletion.

Introduction & Background

The global shift toward electric mobility is essential for reducing carbon emissions and dependence on fossil fuels. However, the sustainability of EVs depends significantly on the management of their batteries after use. Lithium-ion batteries (LIBs), the dominant technology in EVs, contain valuable yet hazardous materials like lithium, cobalt, and nickel. Improper disposal or inefficient recycling can lead to severe environmental consequences. Therefore, understanding and optimizing recycling pathways is vital for the sustainable growth of the EV sector.

Problem Statement

Despite technological advancements, EV battery recycling faces challenges including inefficient material recovery, lack of standardized recycling protocols, and high costs associated with processing. Moreover, limited lifecycle data hinders accurate environmental assessment. There is a need for a systematic evaluation of current recycling practices and their environmental implications through lifecycle analysis.

Objectives of the Study

- 1 To analyze the environmental impacts of current EV battery recycling technologies using lifecycle assessment (LCA).
- 2 To identify key inefficiencies in recycling processes and propose optimized methods for material recovery.
- 3 To develop a framework for sustainable recycling and circular economy integration in the EV battery supply chain.

Literature Review Summary

Previous studies have explored pyrometallurgical, hydrometallurgical, and direct recycling methods for LIBs, each with varying efficiency and environmental footprints. LCA tools such as SimaPro and GaBi have been used to assess emissions and energy consumption, yet few studies combine process-level data with real-world recycling logistics. This research will bridge that gap by integrating existing models with empirical recycling data and sustainability indicators.

Research Methodology

The research will employ a mixed-method approach combining quantitative LCA modeling with qualitative analysis of recycling supply chains. Primary data will be collected from recycling facilities and industry reports, while secondary data will be sourced from scientific databases. The study will utilize ISO 14040/44 standards for LCA. The methodology will include: (1) system boundary definition, (2) inventory analysis, (3) impact assessment, and (4) interpretation for sustainability recommendations.

Expected Outcomes

The research is expected to deliver a detailed lifecycle profile of EV battery recycling processes, identifying the most sustainable and cost-effective methods. Findings will contribute to policy formulation, promote circular economy adoption, and support the development of greener recycling technologies.

Significance of the Study

This study will advance the understanding of sustainable battery management practices and inform both policymakers and industry stakeholders. By identifying environmental hotspots and recovery potential, it will contribute to achieving global sustainability targets and improving EV lifecycle performance.

Timeline & Budget (Brief)

The project is expected to span 12 months, divided into four phases: literature review (2 months), data collection and modeling (4 months), analysis and validation (4 months), and reporting (2 months). A moderate budget will cover LCA software access, data acquisition, and dissemination costs.

References

1. Gaines, L. (2018). The future of automotive lithium-ion battery recycling: Charting a sustainable course. *Sustainable Materials and Technologies*, 17*, e00087.
2. Harper, G., et al. (2019). Recycling lithium-ion batteries from electric vehicles. *Nature**, 575, 75–86.
3. Dunn, J. B., et al. (2021). Circularity of lithium-ion battery materials in electric vehicles. *Nature Sustainability**, 4, 136–145.