Proceedings of the 7th African International Conference on Industrial Engineering and Operations Management
Cape Town, South Africa, May 13-15, 2026

Proceedings of the International Conference on Industrial Engineering and Operations Management

Publisher: IEOM Society International, USA DOI: 10.46254/AF07.20260069
Published: May 13, 2026

Environmental Impacts for Potential to Produce Battery Materials from Waste Biomass

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Abstract

Concerns over critical mineral dependency and life cycle environmental burdens have been raised by the increased demand for battery materials brought on by the rapid shift to electric transportation and grid scale energy storage hence the need for biomass derived carbon materials offer a sustainable substitute for anodes in lithium-ion and sodium-ion batteries. Environmental impact analyses that incorporate both quantitative measurements and qualitative contextualization are still dispersed throughout production scales, feedstock types and technological readiness levels. According to recent life cycle assessment studies, the main environmental hotspot at laboratory scales for biomass derived hard carbon synthesis is the energy consumption of pyrolysis. Significant improvement potential is revealed by prospective upscaling to industrial levels, innovative bio-oil binding processes employing biocarbon derived from sawdust achieve 50% higher yields and 20% lower greenhouse gases emissions than traditional methods, with initial Coulombic efficiency reaching 90% in half-cell tests. However, argon consumption, acid depletion and direct methane emissions are new crucial issues brought about by large-scale operations that call for emission controls and energy recovery systems. With life cycle assessment verifying significant multi-category environmental impact reductions, spent lithium iron phosphate batteries co-processed with walnut shell pyrolysis show decreased carbon dioxide emissions and suppression of hazardous hydrogen fluoride formation via fluorine capture. Biomass conversion technologies including pyrolysis, hydrothermal carbonization and chemical activation transform diverse feedstocks, agricultural residues, forestry byproducts, textile waste and sewage biosolids into porous carbons with tailored microstructures. This waste-to-wealth paradigm offers circular economy alignment, reducing landfill burdens and fossil precursor dependence. Critical challenges persist, feedstock heterogeneity, pore-structure controllability beyond surface area metrics and the persistent laboratory-to-industry scalability gap. Sodium-ion systems using biomass-derived hard carbon exhibit particular promise for stationary storage applications where material abundance and cost outweigh energy density requirements. Although biomass-derived battery materials show quantifiable environmental benefits at scale, achieving their full potential necessitates integrating industrial process engineering with controlled synthesis innovations through focused approaches for emission reduction, solvent substitution and energy efficiency. In the diversified future portfolio for sustainable energy storage infrastructure, biomass derived materials are positioned as a technically feasible and environmentally beneficial component due to the convergence of life cycle assessment standardization, electrochemical performance parity and regulatory pressure for supply chain transparency.

Keywords
Agricultural residues, anode materials, biomass-derived carbon, circular economy, hard carbon, life cycle assessment, pyrolysis, sodium-ion batteries, supply.