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A System Dynamics Approach for Assessing Policy Impacts on Closed-Loop Supply Chain Efficiency: A Case Study on Electric Vehicle Batteries

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Abstract : Electric vehicle battery recycling has emerged as a critical process in the transition toward sustainable transportation. As the demand for electric vehicles continues to rise, so does the need to address the end-of-life management of their batteries. Electric vehicle battery recycling benefits resource recovery and supply chain stability by reclaiming valuable metals like lithium, cobalt, nickel, and graphite. The reclaimed materials can then be reintroduced into the battery manufacturing process, reducing the reliance on raw material extraction and the environmental impacts of waste. Current battery recycling rates are insufficient to meet the growing demands for raw materials. While significant progress has been made in electric vehicle battery recycling, many areas can still improve. Standardization of battery designs, increased collection and recycling infrastructures, and improved efficiency in recycling processes are essential for scaling up recycling efforts and maximizing material recovery. This work delves into key factors, such as regulatory frameworks, economic incentives, and technological processes, that influence the cost-effectiveness and efficiency of battery recycling systems. A system dynamics model that considers variables such as battery production rates, demand and price fluctuations, recycling infrastructure capacity, and the effectiveness of recycling processes is created to study how these variables are interconnected, forming feedback loops that affect the overall supply chain efficiency. Such a model can also help simulate the effects of stricter regulations on battery disposal, incentives for recycling, or investments in research and development for battery designs and advanced recycling technologies. By using the developed model, policymakers, industry stakeholders, and researchers may gain insights into the effects of applying different policies or process updates on electric vehicle battery recycling rates.

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