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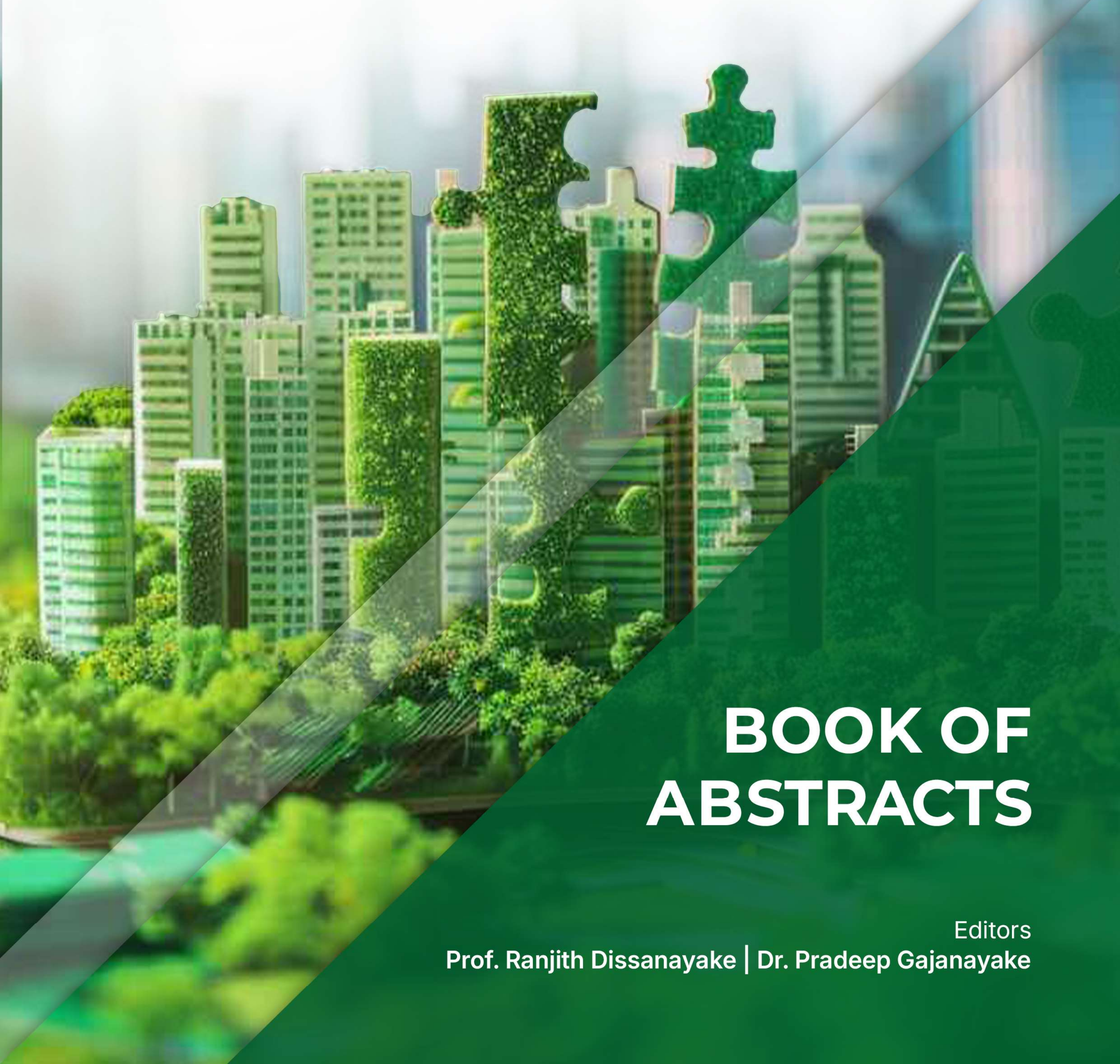

BOOK OF ABSTRACTS

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DESIGNING A SCALE-UP FRAMEWORK WITH LIFE-CYCLE THINKING: ENHANCING THE SUSTAINABILITY OF HCL ACID LEACHING FOR GRAPHITE ANODES IN LITHIUM-ION BATTERY

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Abstract: Lithium-Ion Batteries (LIBs) play an important role in reducing carbon emissions in energy systems, but the environmental impacts of their production are not fully understood. Graphite, widely used as an anode material, requires an HCl acid leaching purification method to meet the performance standards of LIBs. This study presents a conceptual framework to guide the scale-up of HCl acid-leaching purification of Sri Lankan vein graphite, integrating principles of life cycle thinking and preliminary environmental assessment into early-stage process development. The framework aims to bridge laboratory-scale processes and industrial-level planning by supporting preliminary energy and environmental assessment during early process development. Here, the methodology includes five steps: establishing laboratory protocols, designing the process flowchart, scaling independently each process step, linking the steps into a complete system and assessing energy demands. This process involves liquid-phase batch reactions followed by purification and drying stages. The framework models key energy-consuming operations, including reaction heating, stirring and drying, using thermodynamic and geometric scaling laws. This study shows that reaction heating increases linearly from 3.76 to 376 kWh. On the other hand, the heat loss amount rises from 0.04 to 0.77 kWh, with its proportional contribution drops to 19.25% at the largest scale due to improved thermal efficiency. As production scales up, total reaction energy consumption increases from 5.28 to 476.92 kWh. This corresponds to approximately 90% of the theoretical linear scaling. Stirring energy is not behaving linearly and increasing from 0.007 to 0.151 kWh. However, all volumes show that the drying energy remained constant at 13.5 kW. Although limited to laboratory-level data, a foundation path for graphite purification scaling-up processes is provided with this framework. Further, this approach can be applied to related steps and make the completed cradle-to-gate assessments. Overall, this study contributes a structured framework to inform decision-making and supports sustainable industrial transitions in battery material production.

Keywords: Graphite Anode; HCl Acid-leaching Process; Life Cycle Thinking; Lithium-ion Battery; Scale-up Framework