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Evaluating the Impacts of Nanomanufacturing via Thermodynamics and Life Cycle Analysis

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Abstract

The proposed research will develop original life cycle inventory data for the manufacture of polymer nanocomposites, test two new hypotheses for thermodynamics-based Life Cycle Assessment (LCA) and impact assessment with limited information, and develop a tool for exploring economic and environmental aspects of alternate manufacturing combinations for selected nanoproducts and conventional processes. The following hypotheses will be tested: (1) Among alternatives for making similar products, the one with a higher life cycle thermodynamic efficiency has a smaller life cycle impact; and (2) Emissions with a smaller life cycle thermodynamic efficiency have a larger ecotoxicological impact. The second law of thermodynamics and hierarchical systems theory support these hypotheses. However, validating them has been challenging.

Through collaboration with leading academic groups, industry, and a national laboratory, life cycle inventory data and modules will be developed for the synthesis and use of nanoclays and carbon nanofibres. These modules will be combined with life cycle information at different spatial scales, ranging from equipment to ecosystems, and used to perform multiscale or hybrid LCA of several potential products. Different scenarios for the manufacture, use, end of life, emissions and exposure of typical consumable and durable products, such as automotive body panels and food wrapping film, will be analyzed, along with estimates of uncertainty. Thermodynamic LCA will treat industrial and ecological systems as networks of energy flow and combine the features of systems ecology, LCA and systems engineering. The proposed hypotheses will be tested in a statistical sound manner via several case studies.

LCA of nanotechnology is essential for guiding and managing risk in research, development and commercialization, while preventing irrational optimism or unfounded fear of this emerging field. However, it presents formidable obstacles because data and knowledge about resource consumption, and emissions and their impact are either unknown or not readily available. This work will lay the foundation for LCA of polymer nanocomposites and other emerging technologies. Validation of the first hypothesis will provide useful insight about nano versus traditional technologies, while the second hypothesis will provide a proxy for the ecotoxicological impact of the emissions. These hypotheses will be useful for nano and other emerging technologies before detailed emissions data and ecotoxicological studies are available. As more information about manufacturing, emissions and their impact becomes available, it will be incorporated in the proposed studies and tool.