Life Cycle Environmental and Economic Analysis for Engineering Decision Making - A Hybrid Exergetic Approach

Jorge L. Hau, hau@che.eng.ohio-state.edu
Bhavik R. Bakshi, bakshi.2@osu.edu

There is no doubt that consideration of environmental issues in process design requires a life cycle and multi-objective strategy, as opposed to the traditional narrowly focused cost-benefit analysis. However, a formidable challenge faced by this kind of approach is that of evaluating multiple objectives and defining a fair and consistentsystem boundary. As in process LCA, defining the boundary by including only the relevant processes may result in large truncation errors, while expanding it to include all interactions is computationally intractable.

In practice, data and models are available at multiple scales ranging from individual equipments and processes, to the supply and demand chains, to the economy and ecosystem. Nonetheless, indiscriminate combination of such models is prone to unreliable outcomes since data become more aggregated and uncertain at larger scales.

This paper presents a novel multiscale and multiobjective approach for utilizing available information at all these scales and providing the most comprehensive scenario on which process alternatives can be tested and better decisions at the plant scale be made. The multiscale approach is closely related to existing hybrid (tiered) LCA methods (Suh et al.,2004), but represents inputs and outputs in terms of cumulative exergy consumption (CEC) (Szargut et al., 1988). Contribution of labor and capital are also included in the analysis. Exergetic information at equipment and process scales is available from engineering analysis, while that at economy and ecosystem scales is obtained by combining exergy analysis with economic input-output analysis (Ukidwe and Bakshi, 2004).

The proposed methodology considers two objective functions: economic cost and exergy consumption of the process life cycle at multiple scales. Results provided by this methodology consist of a series of Pareto optimal surfaces at various scales. Case studies of a heat exchanger and a cogeneration system compare the proposed approach with existing methods, and highlight the benefits of adopting a multiscale and multiobjective view. Opportunities for retrofitting existing industrial systems are also identified via the proposed approach.

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Department of Chemical Engineering, The Ohio State University, 140 West 19th Avenue, Columbus, OH 43210, USA; tel: +614-292-4944; fax: +614-292-3769.