Article

Expanding Exergy Analysis to Account for Ecosystem Products and Services

Jorge L. Hau and Bhavik R. Bakshi *
Department of Chemical Engineering, The Ohio State University, 140 West 19th Avenue, Columbus, Ohio 43210

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Abstract

Exergy analysis is a thermodynamic approach used for analyzing and improving the efficiency of chemical and thermal processes. It has also been extended for life cycle assessment and sustainability evaluation of industrial products and processes. Although these extensions recognize the importance of capital and labor inputs and environmental impact, most of them ignore the crucial role that ecosystems play in sustaining all industrial activity. Decisions based on approaches that take nature for granted continue to cause significant deterioration in the ability of ecosystems to provide goods and services that are essential for every human activity. Accounting for nature's contribution is also important for determining the impact and sustainablility of industrial activity. In contrast, emergy analysis, a thermodynamic method from systems ecology, does account for ecosystems, but has encountered a lot of resistance and criticism, particularly from economists, physicists, and engineers. This paper expands the engineering concept of Cumulative Exergy Consumption (CEC) analysis to include the contribution of ecosystems, which leads to the concept of Ecological Cumulative Exergy Consumption (ECEC). Practical challenges in computing ECEC for industrial processes are identified and a formal algorithm based on network algebra is proposed. ECEC is shown to be closely related to emergy, and both concepts become equivalent if the analysis boundary, allocation method, and approach for combining global energy inputs are identical. This insight permits combination of the best features of emergy and exergy analysis, and shows that most of the controversial aspects of emergy analysis need not hinder its use for including the exergetic contribution of ecosystems. Examples illustrate

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the approach and highlight the potential benefits of accounting for nature's contribution to industrial activity.

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