454d Network Analysis of Industrial and Ecological Systems and Its Implications to Sustainable Engineering

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Ecological networks provide goods and services that are the foundation of industrial activity. Examples of ecosystem services include the sedimentary cycle, necessary for concentrating minerals for mining; the hydrological cycle, which creates rain; and river and ocean currents, which dilute pesticide runoff. Ecosystem goods include fossil fuels, water, and oxygen. Despite their importance, most engineering decision making tends to ignore the crucial role of this natural capital. Resolving the conflict between industry and the environment requires techniques for considering the broader ecological impacts of industrial activities, and methods for the joint analysis of industrial and ecological networks.

In response to these needs, the method of life cycle assessment (LCA) has been developed and has become a popular and standardized approach for comparing alternative engineering decisions and policies. LCA aims to consider the resource consumption and emissions from processes in the entire life cycle of the selected product. This presents formidable challenges due to the large data requirements and complex life cycle networks. However, research over the last decade has resulted in many methodological advances and data representing the complex life cycle networks is becoming available. These data combine detailed engineering knowledge, large-scale network models of the economy, and government data about resource consumption and emissions. LCA typically ignores the role of ecosystems, but we have recently overcome this shortcoming by combining LCA network models with those of ecosystems via the common currency of exergy flow [1,2]. The result is a large input-output network model of ecological and economic systems.

This presentation will focus on the analysis of life cycle networks with and without consideration of natural capital. To the best of our knowledge, this is the first application of network theory to life cycle networks of industrial and ecological systems. We will describe the topological features of the network model for the 1997 U.S. economy and compare them with other common networks, particularly of ecosystems. Network characteristics such as keystone sectors, prevalence of top-down versus bottom-up control, and testing of the scaling hypothesis will be presented. We will then describe the approach for extracting life cycle networks corresponding to specific industrial products. This approach will be used to extract and analyze the life cycle network of alternate transportation fuels such as gasoline and corn-based ethanol. Implications of using network theory for analyzing life cycle industrial-ecological systems to sustainable engineering will be presented along with challenges and opportunities for the future.

References:

1. Hau, J. L., and B. R. Bakshi, Expanding Exergy Analysis to Account for Ecosystem Products and Services, Environmental Science and Technology, 38, 13, 3768-3777, 2004

2. Ukidwe, N. U., and B. R. Bakshi, Thermodynamic Accounting of Ecosystem Contribution to Economic Sectors with Application to 1992 US Economy, Environmental Science and Technology, 38, 18, 4810-4827, 2004