Sustainability Aspects in Decision-Making Processes for Biofuel Production and Biobased Products

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Abstract

Integrating low-carbon technologies within biorefineries, with applications targeting energy-efficient separation systems, is essential to achieving net zero emissions in the coming years. To address this target, we investigated potential biorefinery pathways featuring process intensification in the bioethanol and biodiesel industries. The role of separation technologies was determined, and a methodological tool to design biorefinery systems with improved economic and environmental performance was developed. A thermodynamic analysis, comprising an energy and exergy assessment, of all scenarios showed a 10% reduction in the irreversibility rates, and the steam consumption decreased by 20% compared to conventional bioenergy configurations when considering intensified ethanol and biodiesel processes. The renewability exergy index and the average unitary exergy cost were defined as key parameters to assess the efficiency and impact since they represent appropriate metrics to determine the environmental impact and the global performance throughout the configurations' supply chain. Lastly, promising ethanol-derived products (e.g., 1,3-propanediol, diethyl ether, n-butanol, 1,3-butadiene, D-lactic acid, and succinic acid) were evaluated based on the biofuel conversion performance, aiming to diversify biorefinery systems through chemical production and add value to the technological pathways toward lower carbon fuels/products. Among the alternatives, 1,3-propanediol was ranked as the most promising ethanol-derived chemical based on exergy efficiency and λ_{index}.