Consequential Life Cycle Optimization of Algae Biorefinery

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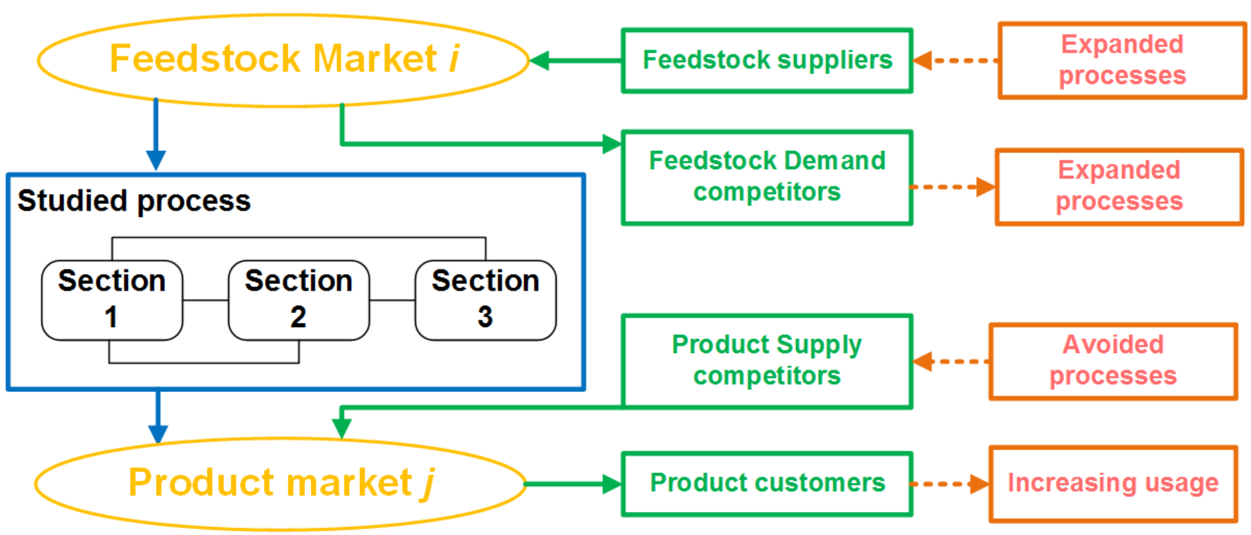
Sustainability has become a critical undertaking in the future development of chemical and petroleum industries. A state-of-the-art methodology for design of sustainable process systems integrates life cycle analysis (LCA), a tool to quantitatively evaluate environmental impacts, with superstructure optimization models. However, the existing contributions only employ attributional LCA, which considers the average operation of a static system and fails to capture the indirect effects and reflect the real-world environmental influences. In order to address this problem, another approach, consequential LCA, can be considered in developing the optimal process systems designs. A consequential LCA study investigates how environmentally relevant physical flows will change in response to possible decisions. It distinguishes from attributional LCA by introducing market mechanisms, which give rise to a sequence of cause-effect relationships in the system under study. Despite its potential, the consequential LCA approach is still premature and there is not a systematic modeling framework to integrate consequential LCA with process design and optimization.



In this project, our goal is to develop a framework for sustainable process design that reflects indirect changes of implementing a process system. We will expand the system boundary to include essential components for conducting a consequential LCA, and determine how these components interact, as well as how such interactions can be translated and integrated into a mathematical model. We will develop a multi-objective mixed integer nonlinear programming framework to integrate process model and market equilibrium model. The proposed framework will be used to obtain the optimal process performance of an algae-based bioconversion system, and the results will be compared with those from using a conventional attributional LCA approach.