Sustainable Value Chain Design for Biorefineries

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Sustainable Value Chain Design for Biorefineries

Sustainable value chains are an important element to achieve the UN 2030 Sustainable Development Agenda (SDA) [1]. For this purpose, an integrated biorefinery is an essential concept for the sustainable production of food, chemicals and power generation, utilizing e.g. lignocellulosic waste from agricultural waste as feedstock [2]. The crux of this concept is a poor economic potential due to the multitude of costly process steps. [3]. Therefore, the process design of a new biorefinery has to be performed systematically [4]. Besides, designing the process and the utilized feedstocks, special focus lies on the selection of products, since they will determine the overall profitability. Only by optimizing the integration of feedstock, biorefinery processes and co-products, the whole value chain will be both economically viable and sustainable [5].

In detail, the systematic approach to design a sustainable value chain with a biorefinery in its core avails methodologies from Process Systems Engineering and comprises three main steps: (1) Process Design, (2) Process Optimization and (3) Value Chain Optimization. (1) In the first step, first-order models for possible unit operations in a biorefinery are developed, calibrated and validated with own experimental and literature data. Together with a combined Uncertainty and Sensitivity Analysis quantifying the model robustness, surrogate models are developed. These models are integrated into a superstructure, which is then optimized to yield an optimal process design. (2) With the optimal design, the process is optimized both unit-wise and plant-wide. Primarily, this serves to find optimal operation conditions for the process units and to develop scheduling and control strategies for the process. Furthermore, it iteratively gives feedback for the extension of the process design, by increasing the overall utilization of the feedstock by co-production strategies and performing process integration and intensification. (3) Finally, by including feedstock and product markets in the optimization, the whole value chain is displayed. Besides a risk-based economic evaluation, different assessments, e.g. on the life-cycle are performed. This results in several target indicators for the value chain.

Apart from design heuristics and instigations for development of microorganisms and processes for the optimized biorefinery, the result is an overall proof of the economic viability of the value chain with a biorefinery as part of a sustainable production pattern, perfectly matching the goals of the UN-SDA.

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