Techno-Economic Analysis and Life Cycle Assessment for Guiding Bioenergy Pathway Development

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Introduction

The Center for Bioenergy Innovation (CBI) is a bioenergy research center with the objective of enabling innovations across the bioenergy supply chain, from feedstock production through fuel and chemical end products.

The Economic and Sustainability Analysis team applies techno-economic analysis (TEA) and life cycle assessment (LCA) to the pathways under study.

This analysis compares the process economics and key life cycle sustainability metrics of two processes that produce ethyl-butyrate from corn stover: enzymatic deacetylation and mechanical refining (DMR), here treated as a baseline, and consolidated bio-processing with co-treatment (CBP), which is under study by CBI.

Objectives

- Quantify the economic and sustainability impacts that achieving engineering targets can have on a bioenergy pathway.
- Identify hot spots and prioritize drivers for reducing costs and improving sustainability in the CBP process through targeted research efforts.
- Assess the economic and sustainability benefits and trade-offs that exist within these integrated bioenergy systems.

Methods

Techno-Economic Analysis

Aspen models of both ethyl-butyrate processes were developed based on empirical and theoretical input data provided by CBI researchers.

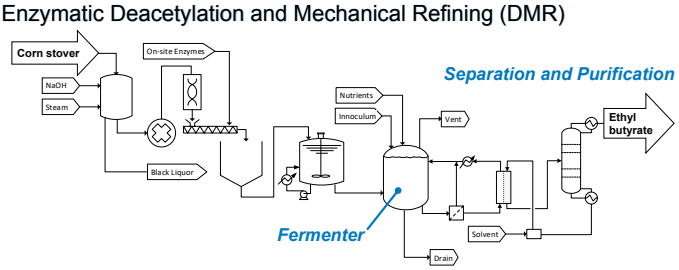
Life Cycle Assessment

SimaPro v. 8.5.2.0 was used to model the two process life cycles, based on material and energy inventories developed as part of the TEA.

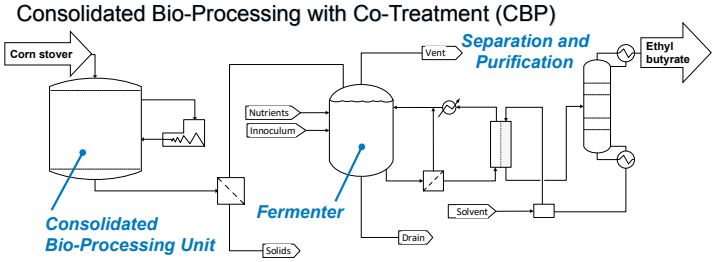
Key upstream processes including corn farming were adjusted to match current U.S. conditions.

Process Diagrams

Enzymatic Deacetylation and Mechanical Refining (DMR)

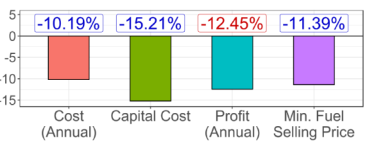


Consolidated Bio-Processing with Co-Treatment (CBP)



Techno-Economic Metrics

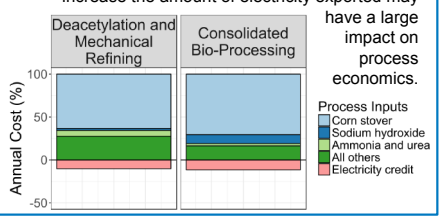
CBP Metrics:
Percent Difference from DMR Baseline



Although fuel yield and annual profits are lower for CBP, reduced capital and operating costs result in a lower MFSP and competitive process.

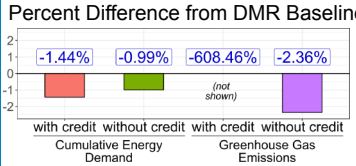
Annual Cost by Process Input

Engineering targets that reduce stover cost and increase the amount of electricity exported may have a large impact on process economics.



Life Cycle Sustainability Metrics

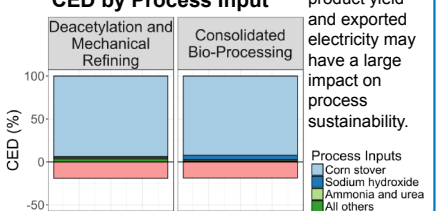
CBP Metrics:
Percent Difference from DMR Baseline



Both processes export electricity to the grid; results are shown with and without credit for this electricity export.

CED by Process Input

Increasing product yield and exported electricity may have a large impact on process sustainability.

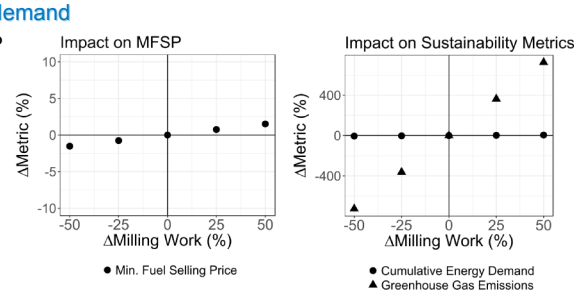


Evaluating the Impacts of Engineering Targets

CBI researchers working in consolidated bio-processing have identified a reduction in required corn stover milling and the microorganism pH tolerance as potentially high-impact engineering targets to pursue.

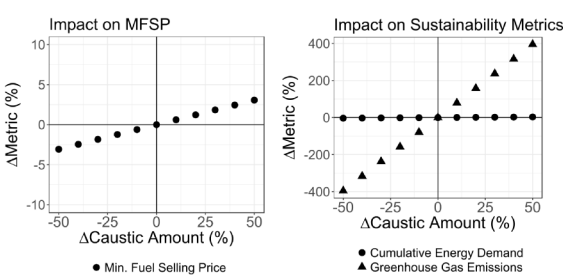
Target 1: Reduce co-treatment milling energy demand

- Corn stover is cycled through a mill during CBP to decrease biomass particle size and promote sugar solubilization.
- Reducing the milling cycles or power demands (e.g. minimize inhibitors affecting solubilization, optimal mill design) will increase electricity available for export in the process.
- **Reducing the milling energy has relatively low impacts and may not be worth pursuing. This target may also have implications for downstream processing.**



Target 2: Increase microorganism pH tolerance

- Caustic (NaOH) added to the CBP vessel maintains a neutral pH environment in which microorganisms can survive.
- Increasing the microorganism pH tolerance allows the amount of NaOH to be reduced, decreasing material costs, CED and GHG.
- **Increasing the pH tolerance has moderate impacts and may be worth pursuing, depending on the effort required to further engineer the microorganism.**



Conclusions and Next Steps

Conclusions

- TEA and LCA provide economic and sustainability context that allows the identification and prioritization of high-impact engineering targets.
- Existence of electricity off-sets can complicate interpretation of TEA and LCA results.
- Additional input is required to determine conclusively which engineering targets are worthwhile – the estimated effort to achieve a target should be taken into account along with the target's potential impacts.

Next step: Further model development

- This analysis is a first step towards developing an integrated techno-economic/life cycle model that can be applied to a wide range of bioenergy and biofuel life cycles.

Next step: Expand current analysis

- Evaluate additional sustainability metrics such as nutrient and water efficiency.
- Explore the economic and sustainability impacts of alternative lignocellulosic feedstocks, conservation farming practices, and changes in CBP process yield.

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