Optimizing Biorefinery Design and Operations via Linear Programming Models

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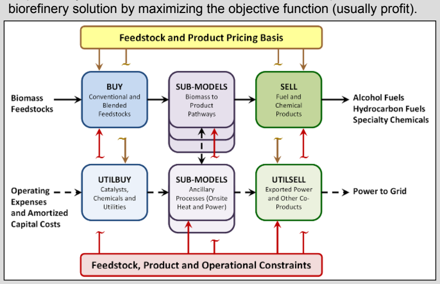
Abstract

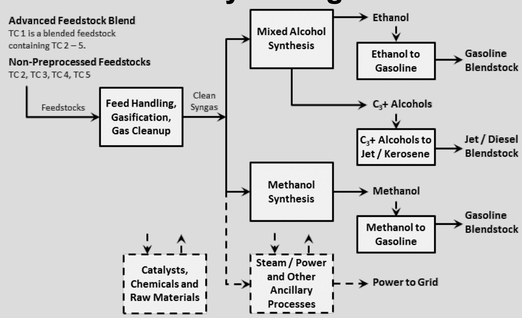
The ability to assess and optimize economics of biomass resource utilization for the production of fuels, chemicals and power is essential for the ultimate success of a bioenergy industry. The team of authors, consisting of members from the National Renewable Energy Laboratory (NREL) and the Idaho National Laboratory (INL), has developed conceptual biorefinery linear programming (LP) models to enable the optimization of conceptual or existing biorefineries. The goal of this analysis is to demonstrate how such models can benefit the developing biorefining industry. It focuses on two conceptual biorefinery configurations – one thermochemical and one biochemical – and demonstrates how the biorefineries can use LP models for operations planning and optimization in comparable ways to the petroleum refining industry. Using LP modeling tools developed under U.S. Department of Energy's Bioenergy Technologies Office (DOE-BETO) funded efforts, the authors investigate optimization challenges for the conceptual biorefineries such as (1) optimal feedstock slate based on available biomass and prices, (2) breakeven price analysis for available feedstocks, (3) impact analysis for changes in feedstock costs and product prices, (4) optimal biorefinery operations during unit shutdowns / turnarounds, and (5) incentives for increased processing capacity. These biorefinery examples are comparable to crude oil purchasing and operational optimization studies that petroleum refiners perform routinely using LPs and other optimization models. It is important to note that the a nalyses presented in this article are strictly conceptual and based on assumed values for energy market prices. The pricing structure assigned for this demonstrative analysis is consistent with $4 per gallon gasoline, which clearly assumes an economic environment that would favor the construction and operation of biorefineries. The analysis approach and examples provide valuable insights into the usefulness of analysis tools for maximizing the potential benefits of biomass utilization for production of fuels, chemicals and power.

LP Modeling Approach

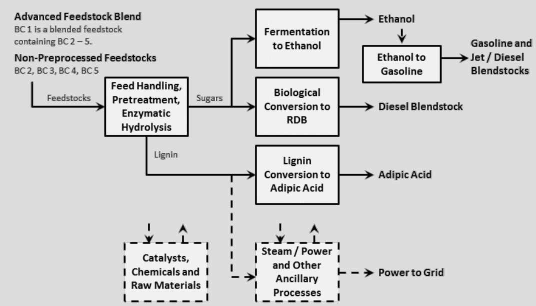
Feedstocks costs, operating costs, capital costs, feed and product pricing structure and simple process models (sub-models) are assembled in the LP to build the conceptual biorefinery models. The sub-models are based on process yields and costs from TEA results. The LP optimizes the biorefinery solution by maximizing the objective function (usually profit).



Modeled Thermochemical Biorefinery Configuration



Modeled Biochemical Biorefinery Configuration



Examples Scenarios from LP Models

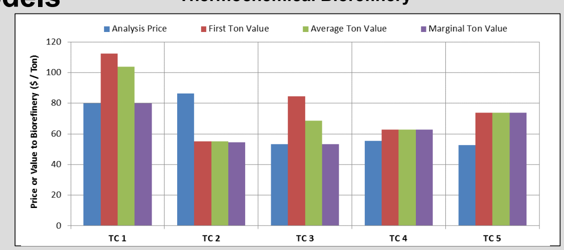
Feedstock Breakeven Value vs. Purchase Price:

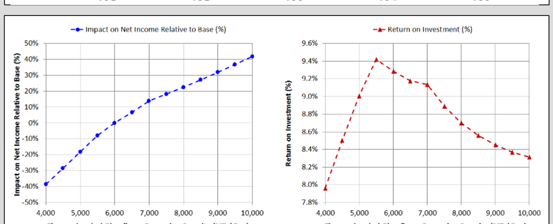
When "value" is greater than the feedstock cost, the biorefinery will profit from processing the feedstock. If the value is less than the feedstock price, the biorefinery will not process the feedstock unless it is forced to take the feedstock due to a constraint (such as minimum unit processing capacity). This LP analysis can provide valuable insights for negotiating feedstock purchasing contracts. In the case of preconstruction scenarios, biorefinery investors can assess the optimal biorefinery design configuration with LP tools while considering anticipated feedstock supply and demand pricing impacts with increased utilization.

Biorefinery Design Capacity Optimization:

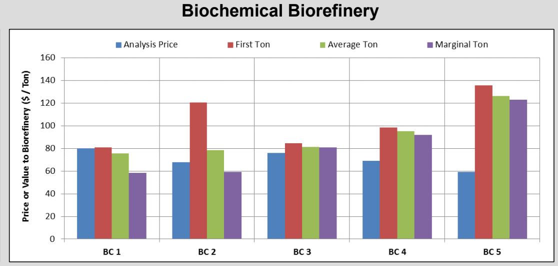
If the project is in pre-construction, LP models can provide insight into design considerations like overdesign of unit capacities to allow flexibility in operations and optimization of the biorefinery. Additional design capacity will increase the capital investment costs for the biorefinery. Therefore, the appropriate objective function for this analysis example is the annual net income with capital depreciation / amortization. In the figures, the impact on net income and return on investment are assessed as functions of biorefinery design capacity. The inflection points represent the biorefinery exhausting supplies of attractive feedstocks and the shift to less attractive options.

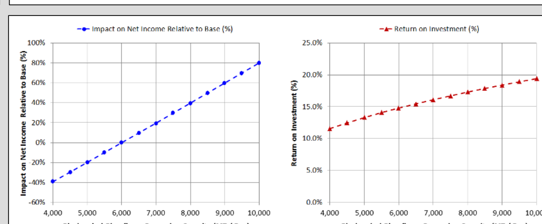
Thermochemical Biorefinery





Biochemical Biorefinery





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The information presented in this poster represents on-going LP modeling and analysis developed in collaborative efforts between NREL, INL and other national laboratories. Quantitative analysis results will be presented in future publications on the LP work. For more information, please contact Michael Talmadge or Patrick Lamers.

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