SENIOR CAPSTONE/ SENIOR DESIGN EXPERIENCE 2025

Ion Exchange Purification of Crude Biodiesel

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Objective

Develop an isotherm for modeling the removal of soap from biodiesel via ion exchange resin.

Background

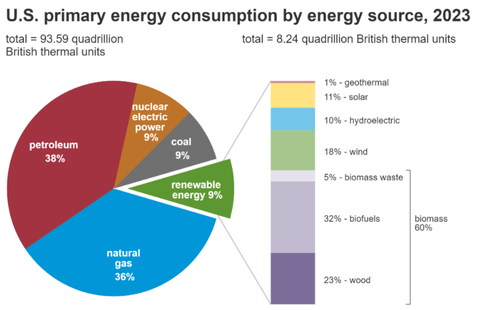


Figure 1: Data source: U.S. Energy Information Administration, Monthly Energy Review, April 2024. Table 1.3 and 10.1.

- Production has gone from 0 gallons per year in 2004 to 2 billion in 2019
- The median plant size in the U.S. produces 20 millions gallons per year

Impact

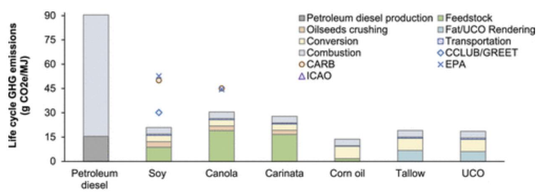


Figure 2: Chart from Hui et. al, Figure 2a. See References.

- Reduced emissions compared to other fuels.
- Renewable source of energy.

Alternatives

Acid Base Catalyst:

- Better for high FFA oils like waste oil
- Longer reaction times

Supercritical Methanol Method:

- No catalyst required for high yield
- Expensive in equipment and energy

Experimental Overview

Produce 1L crude diesel

Purify ~500 mL of biodiesel

Test soap levels and desired resin mass

Purify various diesel mixtures with resin

Results

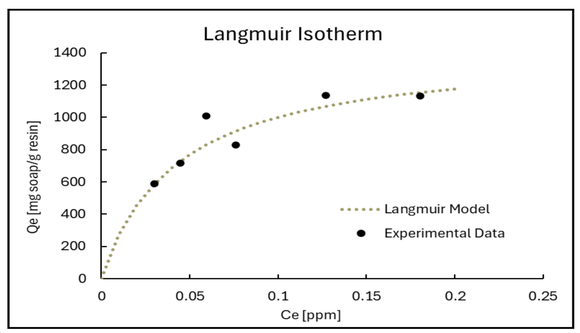


Figure 3: Langmuir Isotherm for Ion Exchange Resin

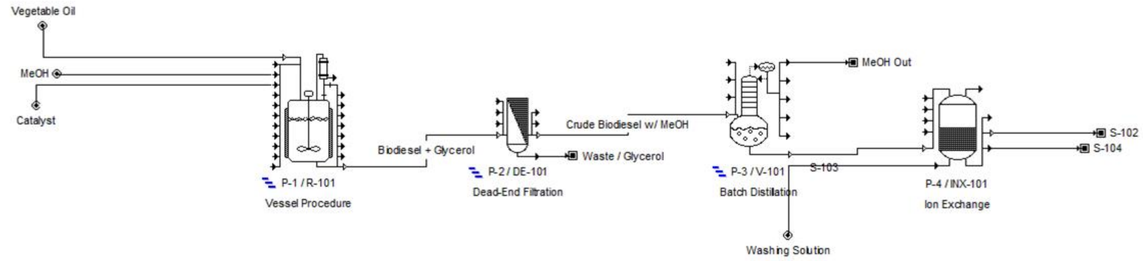
Max Binding Capacity

q_m = 1429 mg Soap/g Resin

Langmuir Constant

K_L = 23.33 g Diesel/mg Soap

Plant Design



Reaction
- 11 Reaction Vessels
- H: 4.41m
- D: 1.7m
- V: 10,000L

Distillation
- 3 Columns
- H: 10m
- D: 6m

Purification
- 2 Columns
- H: 2.58m
- D: 0.86m
- V: 0.749 m^3 resin

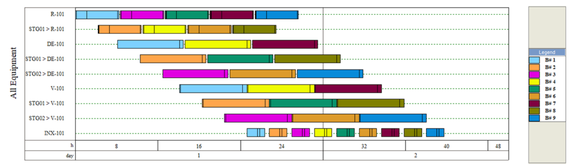


Figure 4: Scheduling chart for unit process down time

Process Optimization

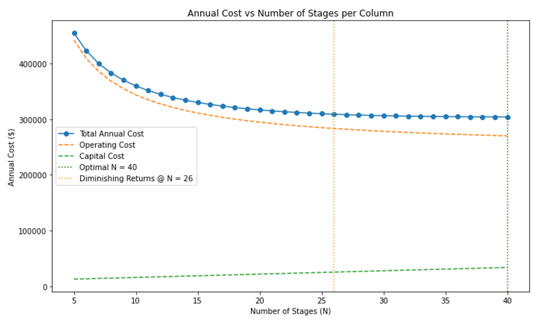


Figure 5: Optimization for number of stages in distillation column

Economic Analysis

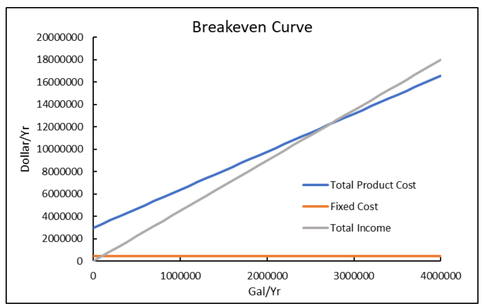


Figure 6: Breakeven curve

- Estimated breakeven production at 2723558 gal/yr at a sales price of $4.5/gal

Future Work

- Improve titration accuracy and resin mass measurements for improved isotherm.
- Max binding capacity and the Langmuir constant can be utilized to inform a plant on resin required to meet ASTM standards.

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