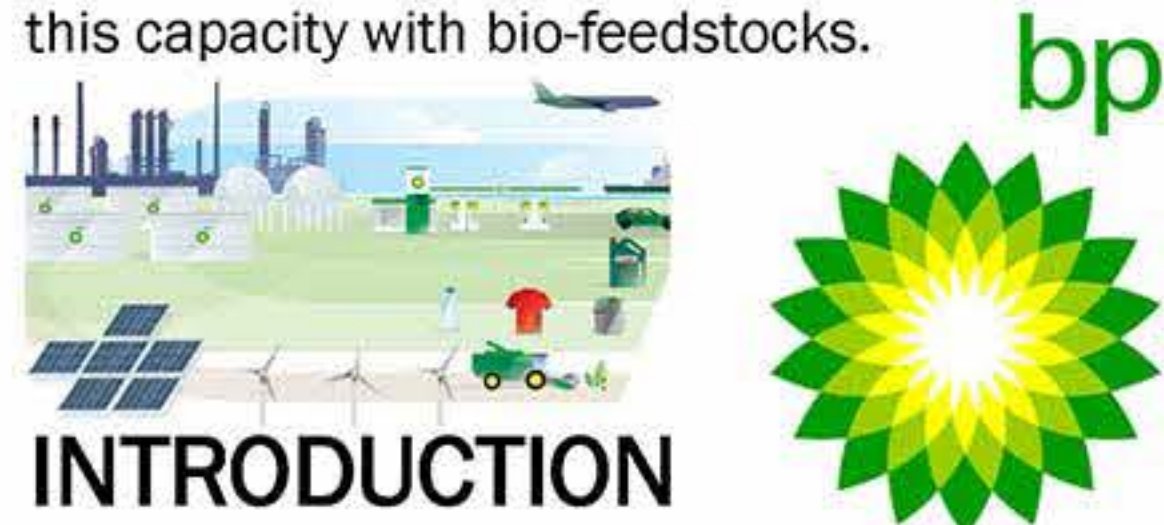


ABSTRACT

Green diesel is a renewable alternative to fossil fuels currently used to power the world. BP's dual energy challenge is an initiative to become carbon neutral by 2050, and the use of green diesel will be essential to attaining this goal. Currently, the BP Cherry Point Refinery co-processes beef tallow in their #3 diesel hydrosulfurization (DHDS) unit. However, both the #2 and #3 DHDS units at BP Cherry Point have extra capacity, 1.4 kbpd and 0.9 kbpd, respectively. The goal of this project is to determine the best way to fill this capacity with bio-feedstocks.



INTRODUCTION

Many options were analyzed to see the most efficient feedstock to fill capacity. Each feedstock was evaluated based on process parameters like pre-treatment, upstream considerations, reaction kinetics, downstream considerations, flow changes, sourcing and final composition properties. This in-depth analysis gave tall oil as the final recommendation. Tall oil is a byproduct of the Kraft paper process, and it was chosen due to availability in the region along with the ability to be implemented into the system.

INITIAL CONSIDERATIONS

- Beef Tallow** – Currently implemented at BP Cherry Point, exceeding current availability
- Choice White Grease** – Swine is not a major market in the Pacific Northwest
- Waste Cooking Oil** – Collection method is not feasible
- Soybean Oil** – Competition with the food industry and complex pretreatment
- Rapeseed Oil** – Minimal pretreatment but complex supply chain
- Tall Oil** – Good market availability but has high capital costs

PRETREATMENT

Crude tall oil (CTO) is the lowest quality tall oil available for purchase. Consequently, pre-treatment steps are required before entering the DHDS units. CTO is primarily contaminated with calcium, sodium, lignin, and wood fibers. In order to remove these components, the calcium is reacted with a dilute sulfuric acid wash to form calcium salts. Then, filters with pores less than 10 microns remove the calcium salts, sodium salts, lignin, and fibers.

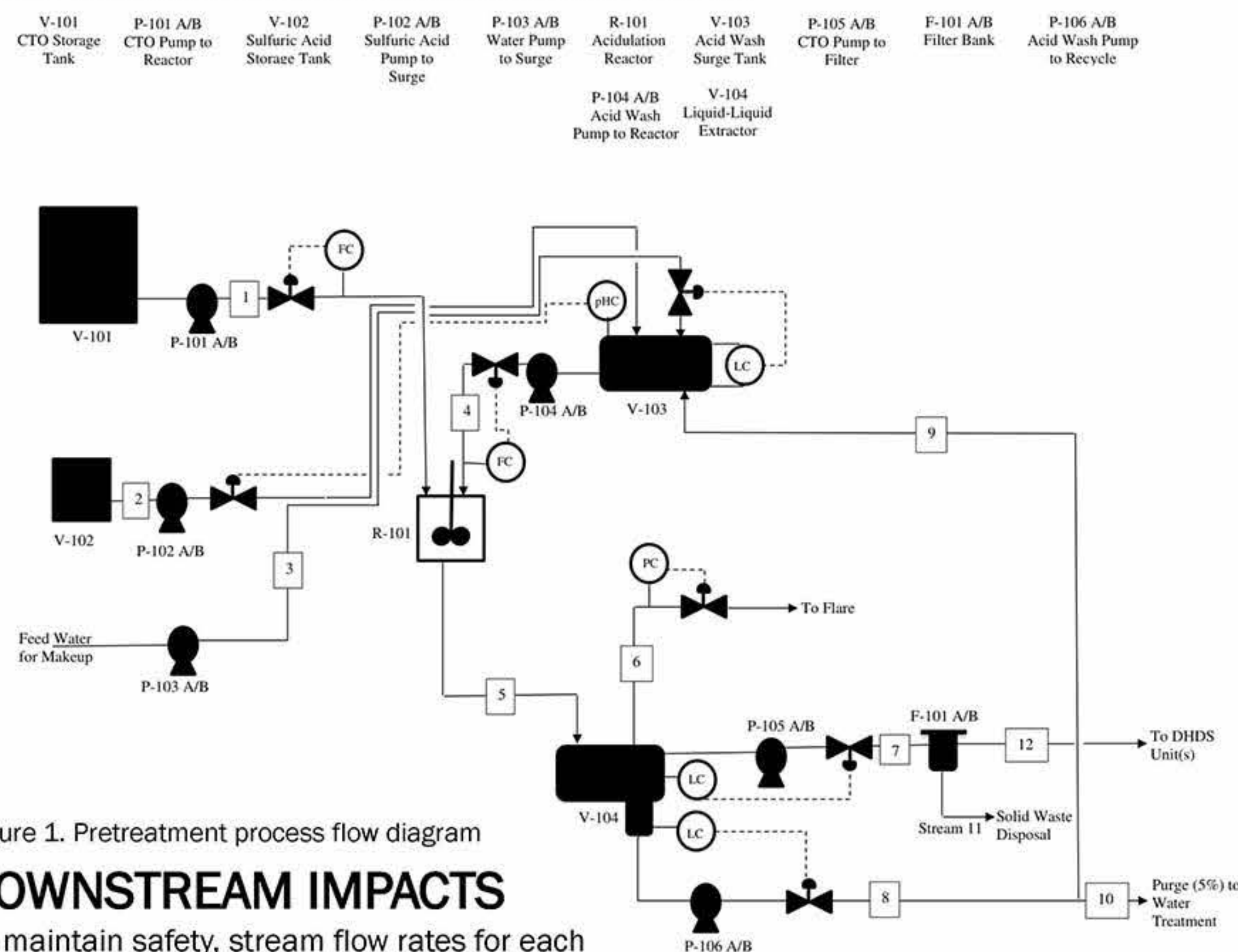


Figure 1. Pretreatment process flow diagram

DOWNSTREAM IMPACTS

To maintain safety, stream flow rates for each DHDS unit and feedstock addition were calculated, giving some notable changes:

- Excess CO₂ in the amine system
- Sulfuric acid added to system from pre-treatment process
- Additional wastewater

The final product has some changes as well:

- Acid value: 0.0016 lbm KOH/lbm
 - Diesel: 0.001 lbm KOH/lbm
- Cloud point mixture: -37.6 °F
 - Diesel: -40°F
- Cetane index for tall oil: 60
 - Diesel: 49

KINETICS

Different reaction process parameters affect conversion and efficiency. Upon hydrotreatment, CTO goes through a deoxygenation reaction to remove the oxygen from the carboxylic acid groups, an isomerization reaction to open the rings of the resin acids, and a saturation reaction to saturate the olefins.

Table 1. Product distribution for the CTO reaction

Conversion (Fatty Acid)	86-94%	617°F-752°F
Conversion (Resin Acid)	90-96%	617°F-752°F
Selectivity Ratio C17/C18	0.66-0.99	617 °F-842 °F
Yield – Diesel Hydrocarbons	84-68%	617 °F-842 °F

SOURCING



Figure 2. Possible sourcing locations for CTO

IMPLEMENTATION COST

Table 2. Costs considered when making the final choice to recommend tall oil (\$350/ton)

Feedstock Cost	\$49,031,378.19
Sulfuric Acid	\$58,327.55
Energy	\$5,071.00
Water	\$85.01
Labor	\$200,730.00
Solid Waste	\$98,412.01
Operating	\$49,394,003.76
Initial Investment	\$2,971,941.35
Overall Cost/yr	\$50,082,618.34
Diesel Revenue	\$93,806,506.96

CONCLUSION

- Costly startup but quick payback period
- More profit than other thoroughly researched option: rapeseed oil
- 90-98% conversion rate
- Smooth implementation into current system
- Abundantly produced and underutilized

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