Generating Biogenic Intermediates Compatible with the Diesel Fuel Infrastructure

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Introduction

This project demonstrates a viable pathway to generate diesel fuel intermediates from forest and agricultural biomass to introduce renewable carbon into the fuel infrastructure and reduce the carbon footprint of a refinery and its fuels. This pilot-scale system produces a diesel fuel blendstock from biomass by gasification, Fischer-Tropsch (FT) synthesis, and Heavy Fischer-Tropsch Liquid (wax) fraction co-processing in a fluidized catalytic cracker (FCC), a conventional refinery unit operation. The synthesis step directly produces liquids that can be blended into diesel fuel and a biogenic wax fraction. The use of this wax intermediate in a standard petroleum refinery to replace fossil-derived materials leverages the multi-trillion dollar refining and product distribution infrastructure already in place for fuels.

- Goal 1: Demonstrate production of diesel fuel blend stock precursor from biomass feedstock
- Goal 2: Facilitate the introduction of renewable carbon into the fuel's infrastructure
- Goal 3: Reduce the carbon footprint of a refinery and fuels it produces

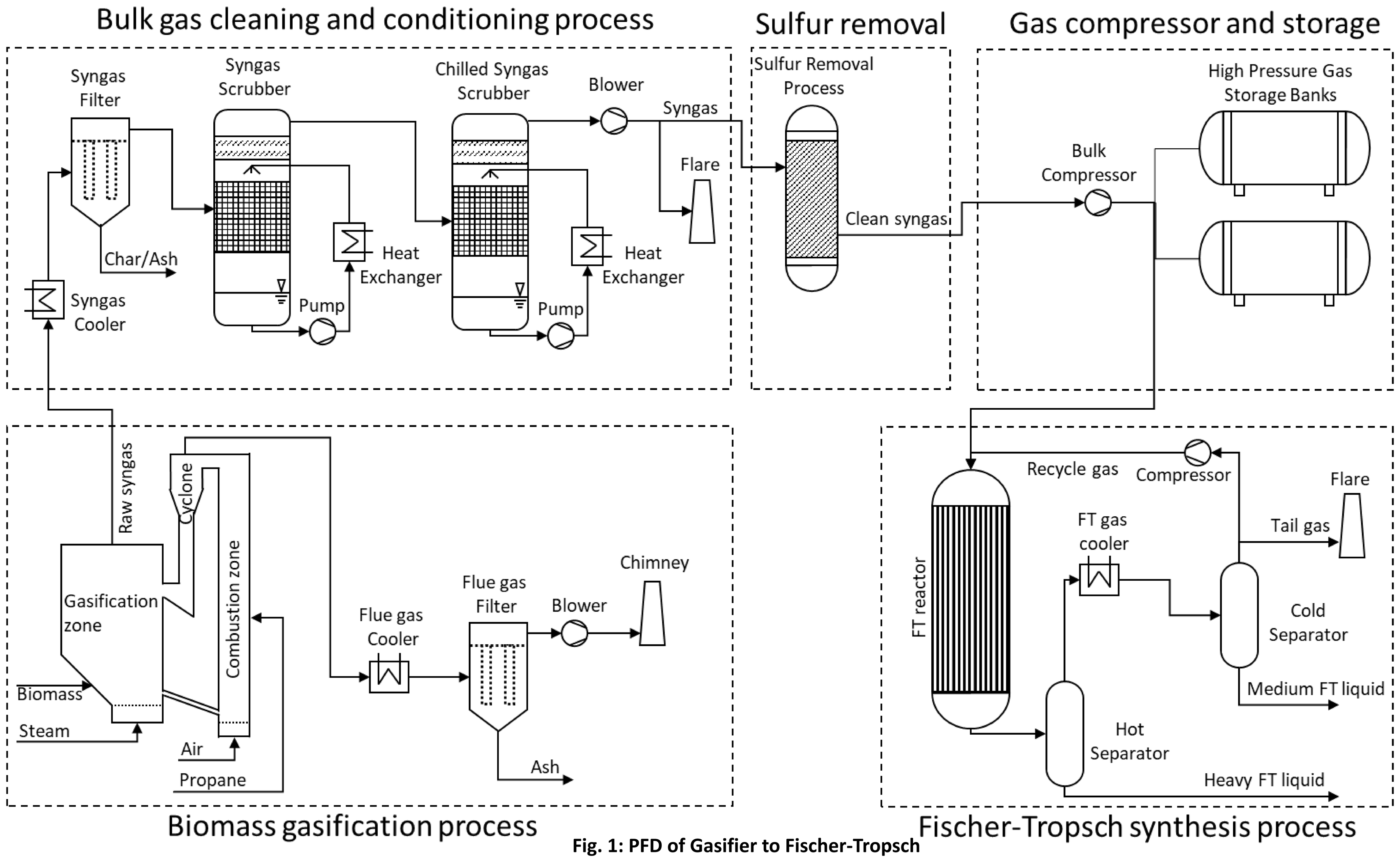

Fig. 1: PFD of Gasifier to Fischer-Tropsch

Fig.1: 1MWt FICFB System, Woodland, CA, USA

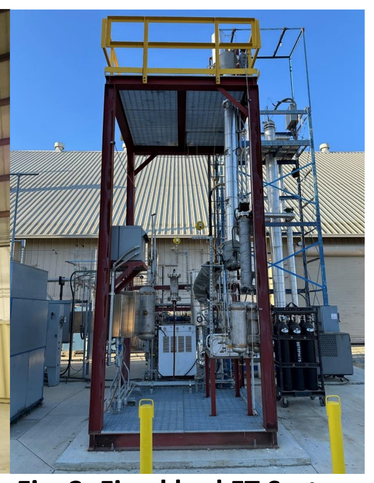

Fig. 2: Fixed bed FT System, Woodland, CA, USA

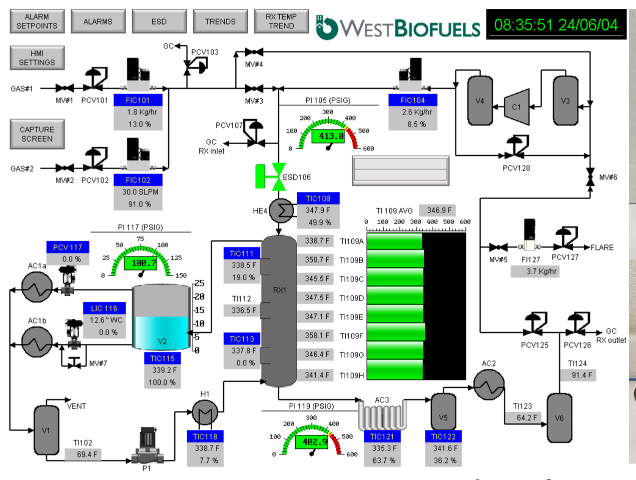

Fig. 3: Low Temp HMI Screenshot of Active FT System

Fig. 4: FT Initial Samples

Materials and Methods

West Biofuels (WBF) operates a 1MWt Fast Internally Circulating Fluidized Bed (FICFB) gasifier with forest and almond tree biomass to produce biogenic syngas. For this project, the gasifier is operated in one-week intervals where the first two days are spent heating the system and following two to three days to capture syngas. The nominal biomass consumption rate during syngas production is 5000 dry kg/day. All biomass must be chipped and sifted to a particle size of 1-4cm in length. The product gas passes through filtration, scrubbing, and sulfur removal to then be compressed into high pressure gas storage banks, fig. 1.

The fixed-bed, Fischer-Tropsch system is a low-temp, boiling-water reactor that utilizes a cobalt based catalyst supplied by Emerging Fuels Technology (EFT). Prior to syngas operation the catalyst was activated with hydrogen at elevated temperatures for extended periods of time. For activation, the water shell of the reactor was drained to reach the higher activation temperatures. WBF purchased manufactured Carbon Monoxide and Hydrogen and used the FT skid to mix them into a binary gas with a ratio of 2.03 (H_2:CO) so that during production the fresh feed combined with the recycle feed of gas enters the reactor at a ratio of 1.9 (H_2:CO). The manufactured gas was blended prior to operation with N_2 at a ratio corresponding to the non-reactant species in the biogenic syngas. The objective was to create a composite gas that is volumetrically representative of biogenic syngas produced by the gasifier for baseline tests. Initial commissioning required that the FT reaction occur long enough to fill the pores of the catalyst before any measurable wax production occurred. With the production of wax, WBF conducted studies with varied process values, table 3. Gas chromatography was used to determine quantity and consumption rate of gas species during operation of both FT and gasifier systems. FT products were analyzed by the National Renewable Energy Laboratory (NREL) and EFT using simulated distillation and gas chromatography-vacuum ultraviolet (GC-VUV).

Results and Continuing Work

West Biofuels has successfully commissioned the FT system with both manufactured and forest syngas and collected samples at different process conditions, figures 4-6. The project is moving into operating the FT synthesis system for an extended period to perform additional testing and produce enough FT products to upgrade and co-process. The goal is to collect performance data on the system, measure process parameters, mass and energy flows, yield and quality to ultimately improve the process. The production will be confirmed by mass and energy balance. Co-processing in an FCC of the FT samples will take place at NREL facilities. WBF will utilize the performance data to complete LCA and TEA evaluations for the commercialization of this renewable diesel pathway.

Operational parameter	Value
Reactor total height	9 m
Combustor ID	24 cm
Gasifier ID (upper/lower)	107/36 cm
Catalyst bed material type	Carbo HSP 30/60
Total catalyst bed material mass	1650 kg
Circulation rate (CFD analysis)	~ 2.53 kg/s
Biomass feed rate (dry)	208 kg/h
Steam flow rate into gasifier	0.192 kg/s
Thermal input	1 MW
Gasifier temperature	800 - 850 °C
Regenerator temperature	950 - 1000 °C
Gasifier exit pressure	+5 - +15 mBar

Table 1: FICFB Gasifier Reactor Operation

Operational parameter	Value
Reactor total height	4 m
Reactor bed tube ID	2.54 cm
Reactor shell ID	23 cm
Catalyst bed material type	Co-based
Total catalyst bed material mass	4.2 kg
FT diesel fraction	25 - 35%
FT wax fraction	50 - 60%
Syngas flow rate	0.8 - 1.0 kg/hr
Bed temperature	176 - 204 °C
ΔT, (T bed –T water)	2.5 - 13°C
Reactor inlet pressure	300 - 400 psig
ΔP,(P inlet – P outlet)	8 - 20 psig

Table 2: Fischer-Tropsch Reactor Operation

	Initial Test conditions					Production Rates		
Case Condition	Temp (C)	Temp (F)	P (barg)	P (psig)	Ratio H2:CO	Syngas Origin	Wax Rate (g/hr)	Avg Liq Rate (g/hr)
WB1- Base	190	375	26	400	1.9	Bottled	39	251
WB2- Low T	200	360	26	400	1.9	Bottled	21	234
WB3- Low P	190	375	21	300	1.9	Bottled	51	234
WB4- Low H2/CO	190	375	26	400	1.55	Bottled	69	228
WB5- High T	196	385	26	400	1.55	Bottled	84	269
WB6- Forest Base	190	375	26	400	1.9	Forest	47	234
WB7- Forest Low Ratio	190	375	26	400	1.55	Forest	57	237

Table 3: Initial Test Conditions and Production Rates of FT Synthesis

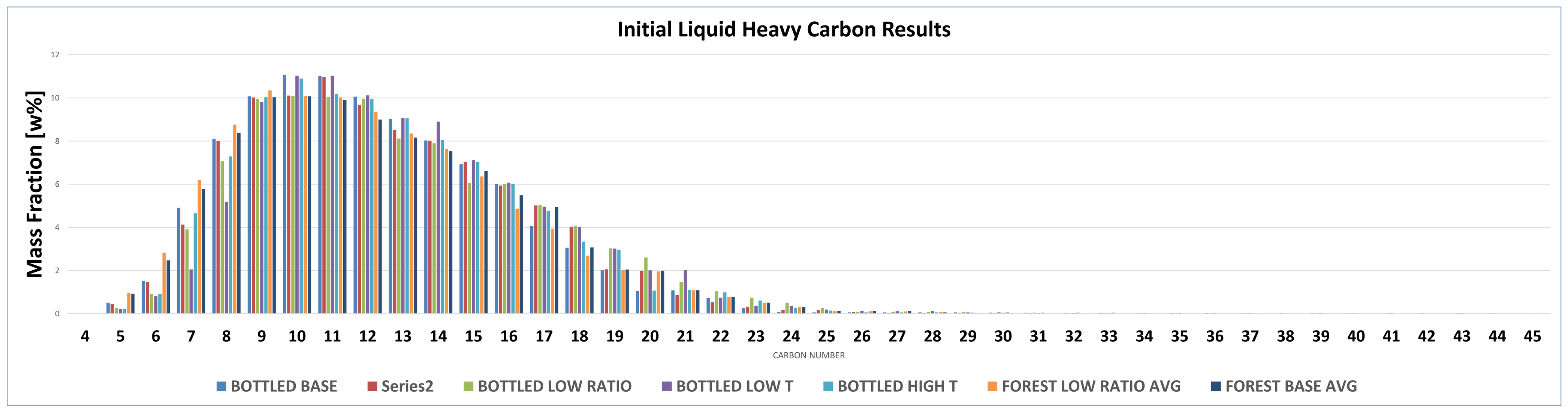

Fig. 5: Initial Light Fischer-Tropsch Liquid Heavy Carbon Results, Analysis Performed by NREL

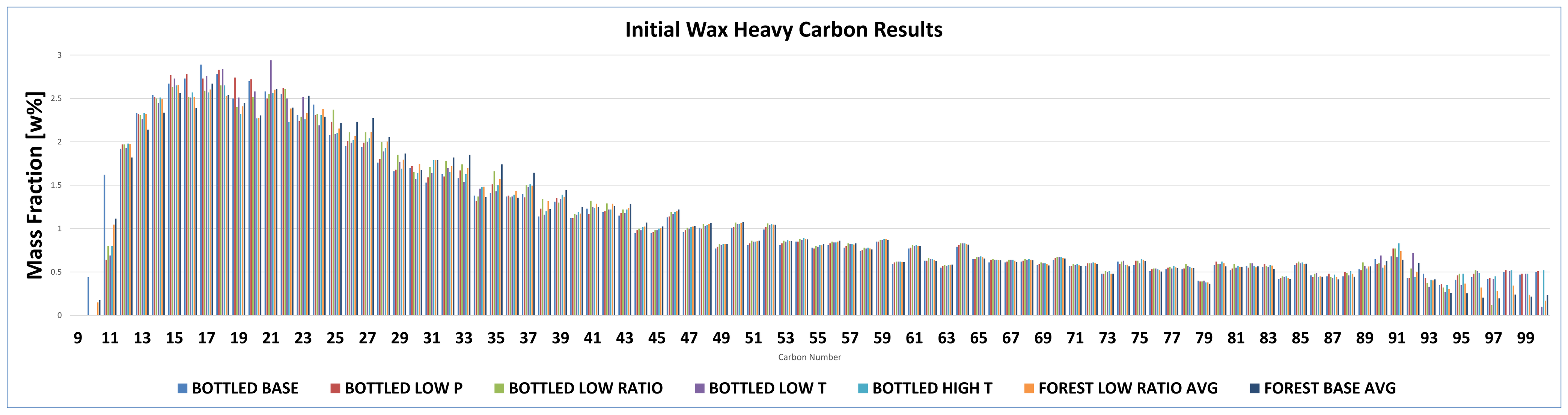

Fig. 6: Initial Heavy Fischer-Tropsch Liquid Heavy Carbon Results, Analysis Performed by NREL

Conclusions

WBF has successfully commissioned a biomass gasification to FT synthesis pathway. The FICFB gasifier has been operational since 2016 but the FT system has now been integrated and brought online. The operational learning curve for the FT skid required a slow approach and led to system improvements before production began. During this initial phase, the team was able to improve the safety and reliability of sample collection, confirm the functionality of safety controls, and develop procedures to bring the reactor into targeted temperature, pressure, and flow for reaction. The reactivity of the bed initially resulted in exotherms which the team learned how to manage to maintain the integrity of catalyst. Ultimately, WBF was able to produce heavy carbon liquids and solids. CO conversion was calculated to be 20% and will be addressed in the next phase to reach the project goal of 50%. Initial analysis show small differences in composition across test cases, but there are noticeable differences in production rates. The alpha value for this system was found to be 0.9, indicating the viability of the catalyst to produce longer chained heavy carbons.

References

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