DOE Bioenergy Technologies Office (BETO) 2023 Project Peer Review

Agricultural and Woody Biomass to Diesel Fuel with FT Intermediate

April 4, 2023
System Development and Integration (SDI) Technology Area

Matthew D. Summers

WestBiofuels

WBS: 3.5.1.304

Project Overview

Project Goals

- Demonstrate the production of a biomass-derived intermediate for upgrading to diesel fuel
- Demonstrate co-processing of the biomass intermediate in conventional refinery equipment
- Facilitate the introduction of renewable carbon into the existing fuels infrastructure

West Biofuels 5 TPD Dual Fluidized Bed Gasification System

NREL Pilot-Scale Davison Circulating Riser Reaction System

Project Overview

Motivation: ***Can a biofuel intermediate from FT process be cost-effectively integrated into existing fuels infrastructure?***

- Diesel demand is steady while gasoline and ethanol are projected to continue to decrease
- Electrification of heavy-duty diesel equipment has major technical hurdles to overcome
- Potential to leverage refinery infrastructure with reduced carbon intensity precursors
- Biomass conversion can be distributed sending intermediate to centralized refineries
- Alternative uses for forest residues and agricultural biomass are needed in the Western U.S.
- All technical steps are at the TRL level that is ready for technical integration
- Support scale-up of multiple, high-volume, cost-effective biofuel production pathways capable of >70% GHG reduction – Stated BETO SDI Goal.

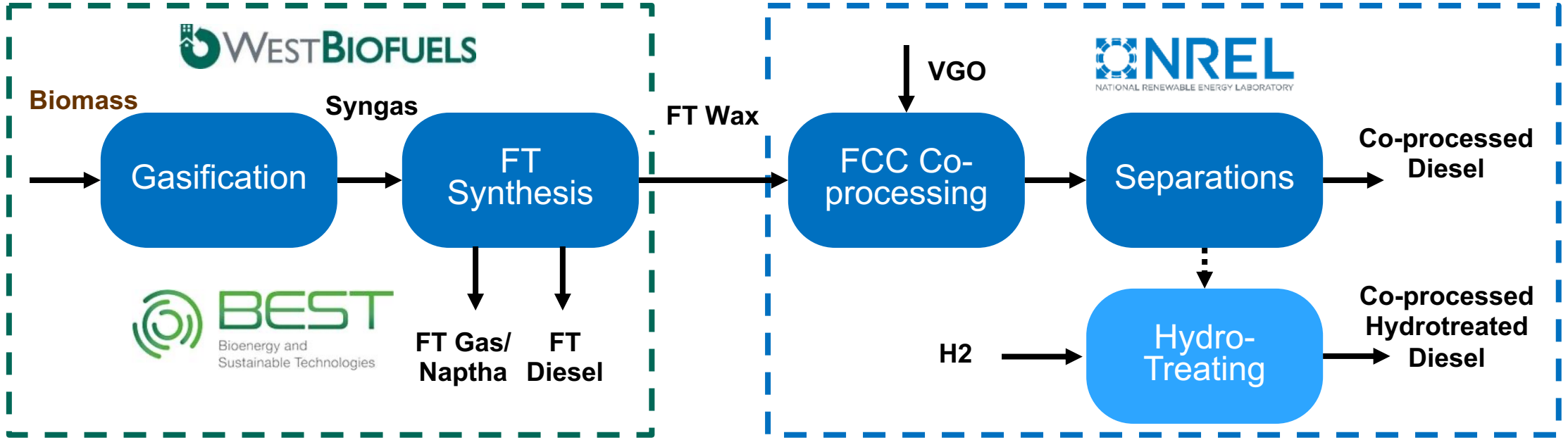
- **Risks:**

- Overall process efficiency and renewable carbon content of the final product
- Challenge of integrating multiple process steps in gasification and synthesis and upgrading
- Reasonable costs for producing intermediate at distributed biomass processing facilities

Project Overview - Team

Project leverages activities at West Biofuels, BEST, and NREL on the major subsystems:

- West Biofuels has existing operating 1-MWth fluidized bed gasifier, gas conditioning equipment, and is installing fixed-bed Fischer-Tropsch (FT) unit
- BEST Research (Austria) recently commissioned 1-MWth gasifier and slurry-bed FT unit
- NREL has been co-processing and hydrotreating bio-liquids with fossil products like VGO and the facilities to produce and test the upgraded diesel products



1. Approach

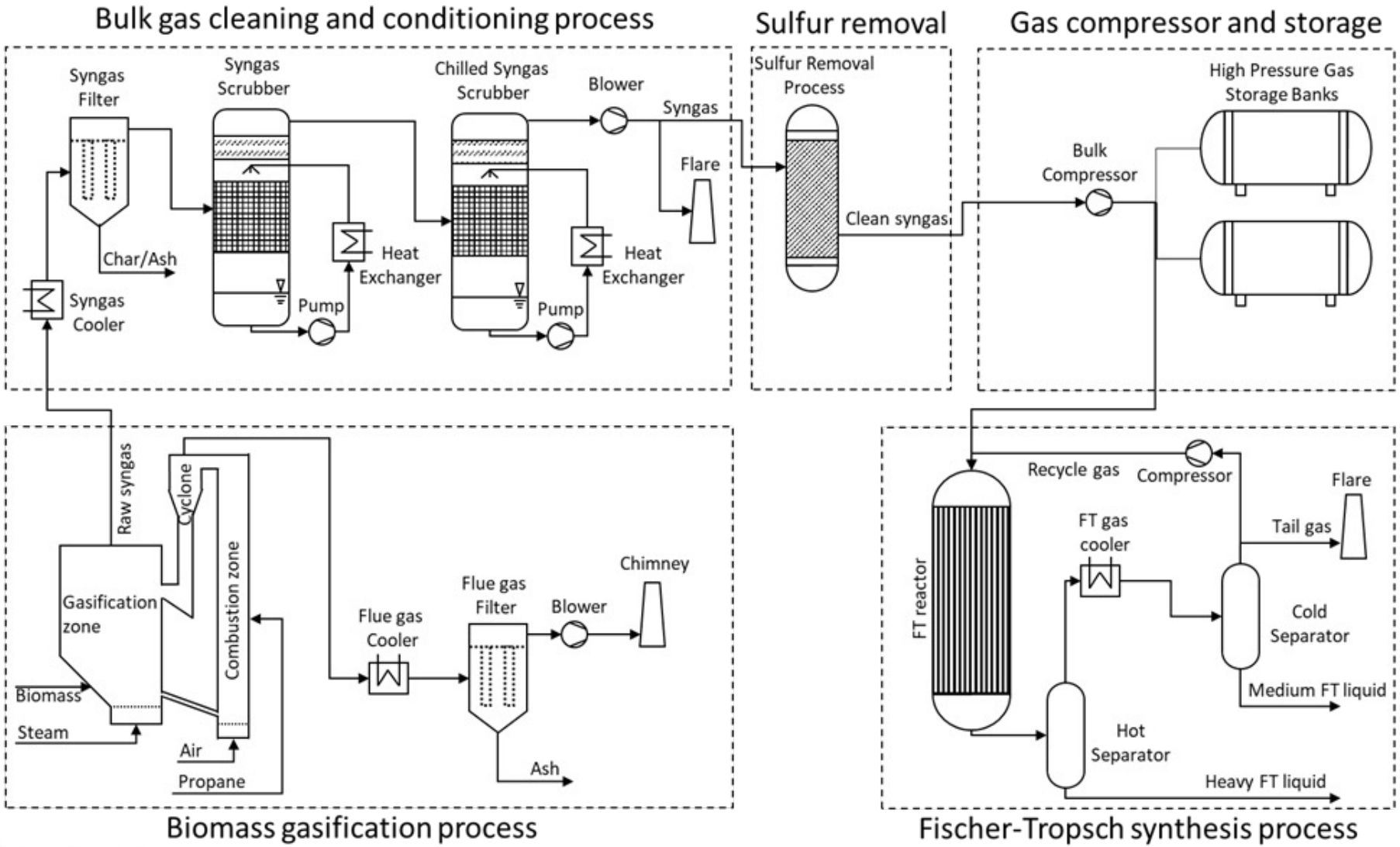
Approach - Demonstrate biomass gasification and Fischer-Tropsch synthesis to produce FT diesel and FT wax as intermediate. Co-process FT wax fraction in FCC pilot plant to produce additional diesel fuel.

- West Biofuels will operate 1-MWth fluidized bed (~5 dry MT per day of biomass input) to produce clean syngas. Compressed syngas is fed to a fixed-bed FT catalyst reactor using a Co-based catalyst and low-temperature synthesis conditions. The FT products are then separated into an FT gas fraction (15-20%), an FT Diesel fraction (25-35%) and an FT wax fraction (50-60%).

- BEST Research will use the same syngas production process but syngas is upgraded in a slurry-bed FT reactor so that the performance of the two approaches can be compared to determine the best option for further commercialization.

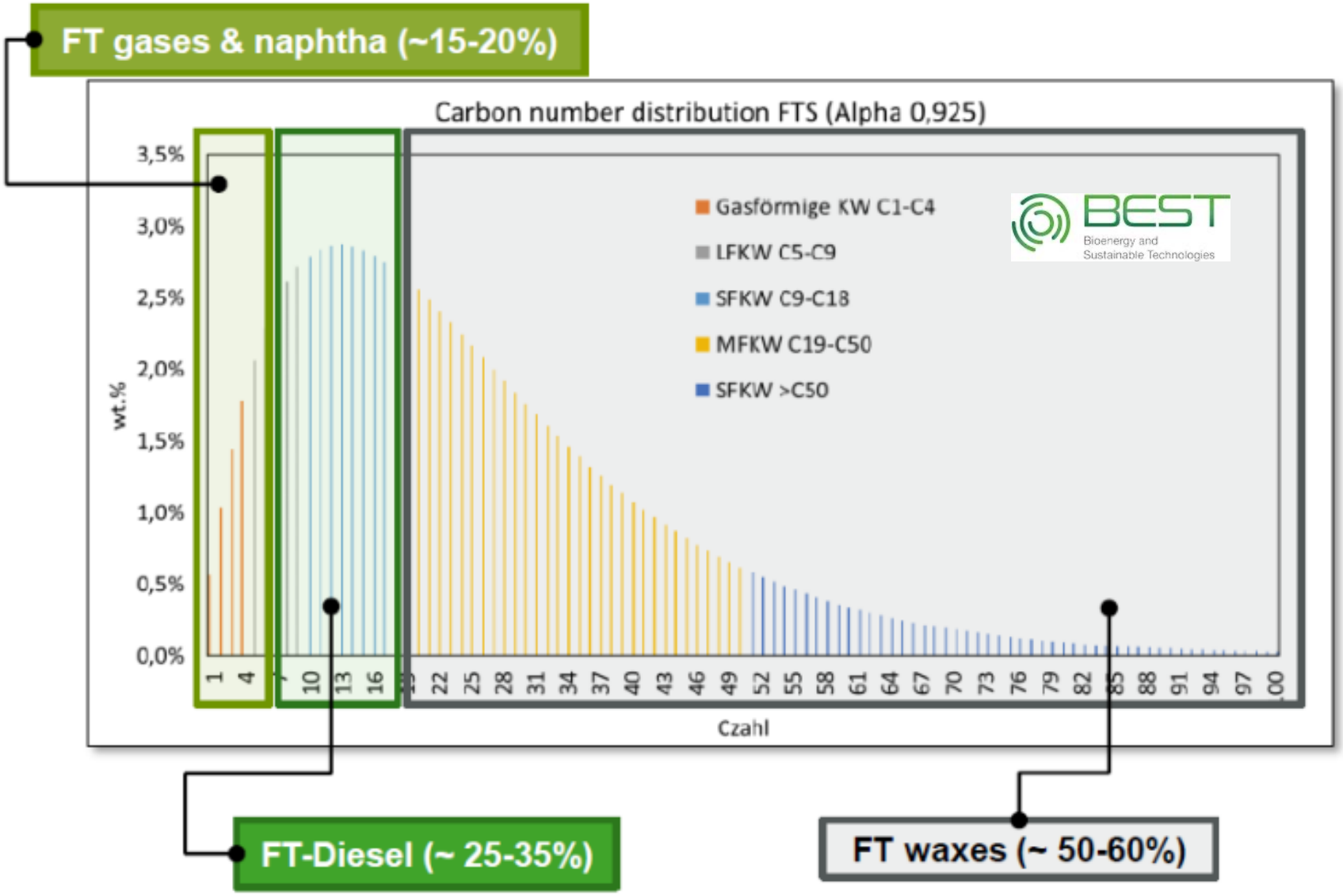
- NREL will co-process FT wax fractions with petroleum-derived vacuum gas oil (VGO) in an existing FCC pilot plant to produce a product high in diesel fuel precursor fractions. In addition, subsequent upgrading by hydro-processing will be investigated to determine the benefits of additional processing to improve diesel properties.

1. Approach – Production of FT Intermediate



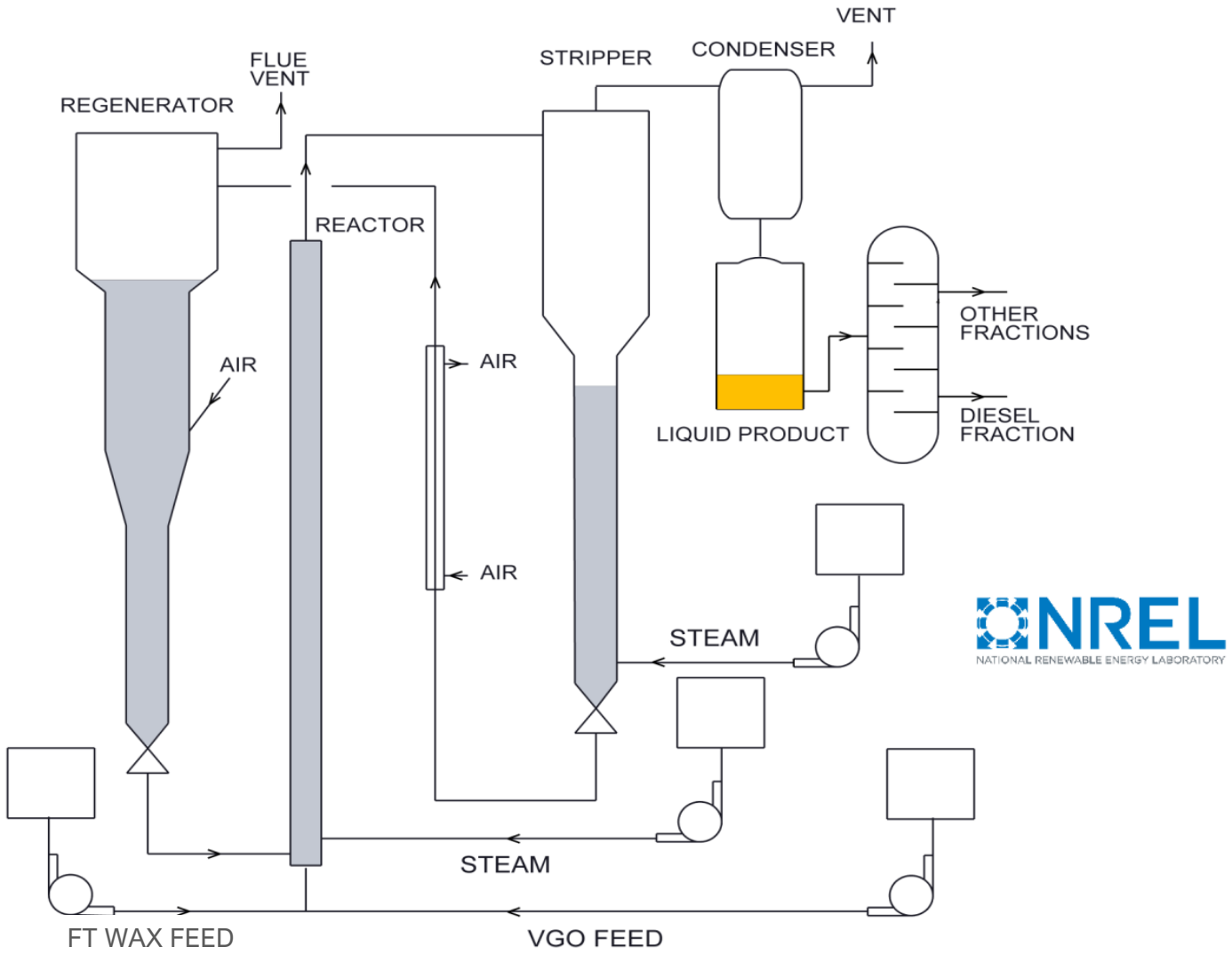
WESTBIOFUELS

1. Proposed Approach – FT Distribution



SOURCE: BEST RESEARCH AND VIENNA UNIVERSITY OF TECHNOLOGY

1. Approach – Co-processing FT Wax to Diesel



FCC co-processing process

1. Approach - Challenges

Name	Description	Mitigation Plan	Probability	Severity
Lower than expected yields of intermediate products	Inhibition of catalyst reactor performance	Change reactor conditions and/or catalyst; modify syngas composition or gas cleaning approach	Medium	Medium
Difficulty co-feeding intermediate wax product	Plugging occurs during co-feeding	Use dual feed, independently heated feed system; adjust blend levels	Low	High
Biogenic carbon efficiency low for preferred pathways	Excessive carbon loss to CO/CO_2 and coke an light hydrocarbons	Change synthesis or co-processing catalysts and/or reaction conditions; Change blend ratio	Medium	Medium
Diesel fuel products do not meet specifications required for blendstock	Physiochemical properties out of range	Trace issue through process; adjust FT synthesis, co-processing, and/or hydrotreating conditions/catalysts	Medium	High

1. Approach – Go/No Go Decision Points

Tasks	Description	Verification Process	Mo #	Qtr #
Task 1:Initial Verification	Project Team presents qualifications, facilities, and readiness of the project	BETO Verification Team determines if the project passes the initial verification based on the criteria outlined	3	1
Tasks 2 – 5: Reaction system and initial studies	Project Team demonstrates process for FT production and co-processing to maximize diesel fuel production that approaches project targets	BETO Verification Team determines if the project has met project targets to proceed with continuous production runs	24	8
Tasks 6 – 11: Continuous production, assessments and plan development	Project Team demonstrates the continuous production of fuel meeting the project targets and the results of the assessments and production plans	BETO Verification Team determines if the project has met project targets from continuous production runs and other objectives	33	11

2. Progress and Outcomes

The project team has had the following progress and accomplishments:

- Completed initial verification Go-No Go Milestone in June 2022
- Operated the dual fluidized bed gasifier system to produce conditioned and compressed syngas
- Installed fixed-bed FT synthesis unit adjacent to the gasifier in Woodland, CA
- Commissioned a dual fluidized bed gasifier system and slurry-bed FT synthesis unit in Vienna, Austria
- Demonstrated co-processing of FT Wax in FCC with significant bio-carbon incorporation
- Demonstrated upgrading of FT Product from FCC to Jet Fuel meeting ASTM specifications

Accomplishment – Operating FICFB Gasifier System

Goal: Develop a 1-MWth dual fluidized bed gasification facility for testing US based feedstocks and various upgraded products from bio-syngas.

Accomplishments

- Completed and commissioned gasification plant in 2015.
- Added gas conditioning and compression capabilities to facility in 2021 and 2022.
- Completed recommissioning after overhaul in 2022.
- Ready for additional syngas production runs for FT system operations and testing.

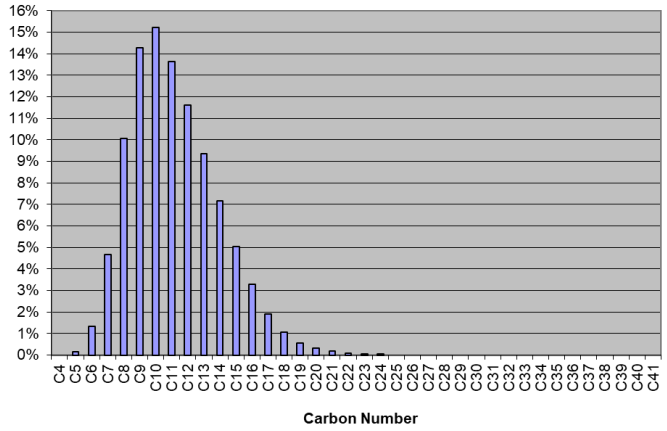
Gas Composition (wet basis)	Woodland FICFB (WB, 2015)	Güssing FICFB Range (Weber, 2013)
H2 (vol%)	33.48%	35% - 45%
CO (vol%)	26.28%	19% - 23%
CO2 (vol%)	16.07%	20% - 25%
CH4 (vol%)	8.27%	9% - 11%
C2H4 (vol%)	1.87%	2% - 3%
C2H6 (vol%)	0.28%	~0.5%
C3H8 (vol%)	0.02%	~0.01%
N2 (vol%)	6.26%	<2%
O2 (vol%)	0.34%	<0.1%
C6 + C7 (vol%)	0.13%	<0.09%
LHV [MJ/kg]	12.60	11.0 - 13.0

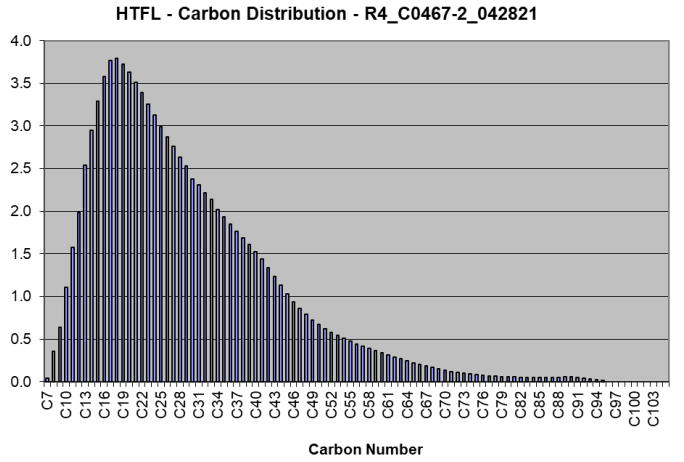
Accomplishment – Installing Fixed-Bed FT Unit

Goal: Add FT synthesis test reactor to Woodland Facility adjacent to gasifier and syngas conditioning and storage facilities.

Accomplishments

- Completed catalyst modeling study to design FT system.
- Completed fabrication of test system.
- Completed mechanical and electrical install of system.
- Currently working on startup and catalyst activation to begin testing.





Accomplishment – Commissioning Gasifier / FT Unit

Goal: Install and commission a biomass gasifier system and a slurry bed FT reactor in Vienna, Austria for testing on forest biomass feedstock.

Accomplishments

- Completed installation of gasifier - May 2022
- Completed commissioning of system - October 2022
- Upcoming test campaigns planned in May 2023 and September 2023 for BETO project.









BEST Bioenergy and Sustainable Technologies

TU WIEN TECHNISCHE UNIVERSITÄT WIEN

LULEÅ UNIVERSITY OF TECHNOLOGY

ÖSTERREICHISCHE BUNDESFORSTE

OMV

SMS group

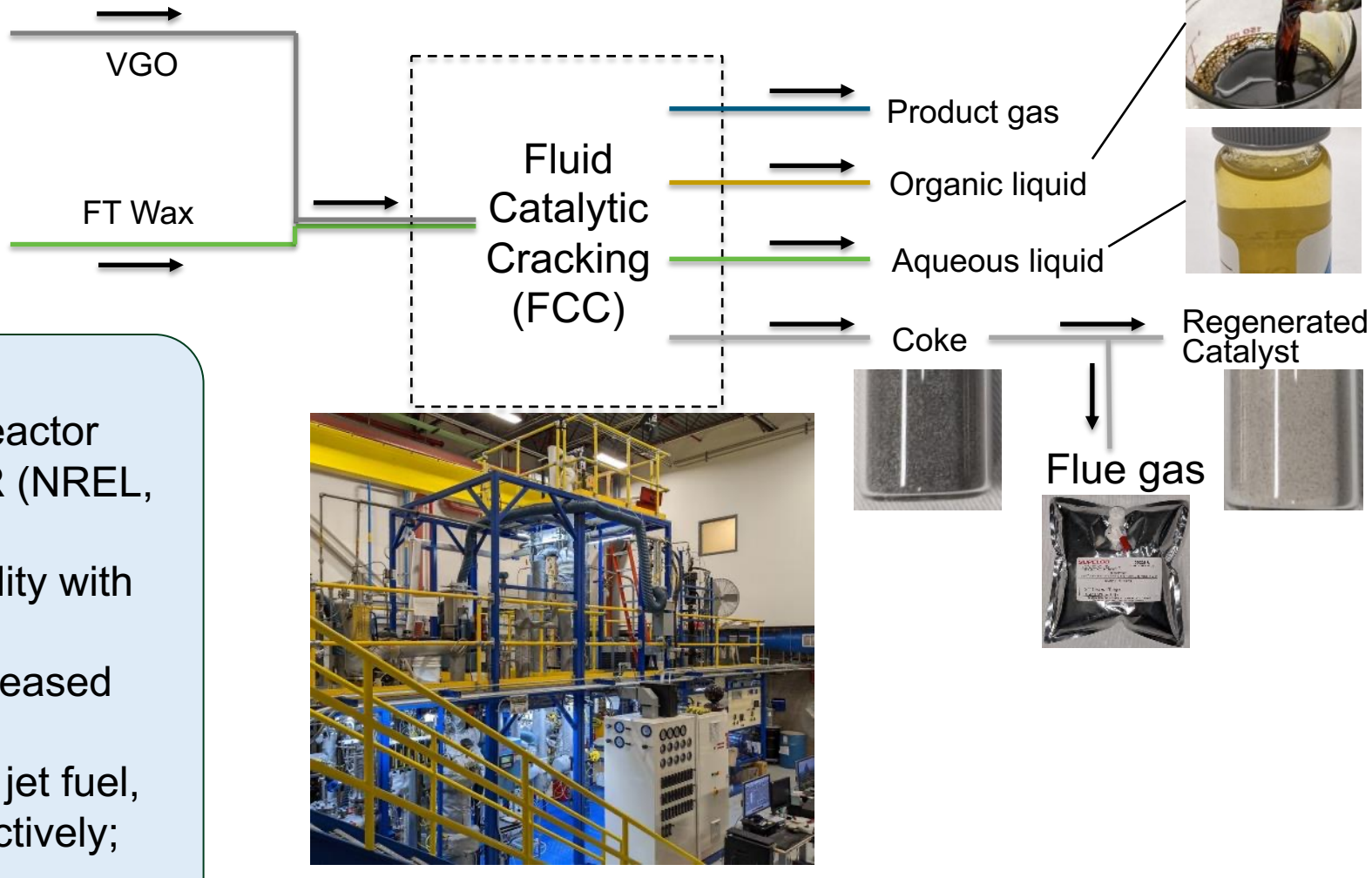
WIENER NETZE

WIENER LINIEN

WIEN ENERGIE

Accomplishment – Co-processing of FT Wax in FCC

Goal: Co-process Fisher Tropsch wax (FT Wax) with Vacuum Gas Oil (VGO) at FCC conditions enabling biocarbon incorporation into gasoline, jet fuel, and diesel.



Accomplishments

- Co-processed 20-40% FT Wax in ACE reactor (Kayser Tech, laboratory scale) and DCR (NREL, pilot scale).
- Results confirm miscibility and compatibility with VGO.
- FT Wax reduced coke formation and increased light olefin formation.
- Biocarbon was incorporated into naphta, jet fuel, and diesel (105%, 50%, and 46%, respectively; relative to fossil carbon from VGO)

Davison Circulating Riser (DCR)

Accomplishment – Upgraded FCC Product to Jet Fuel

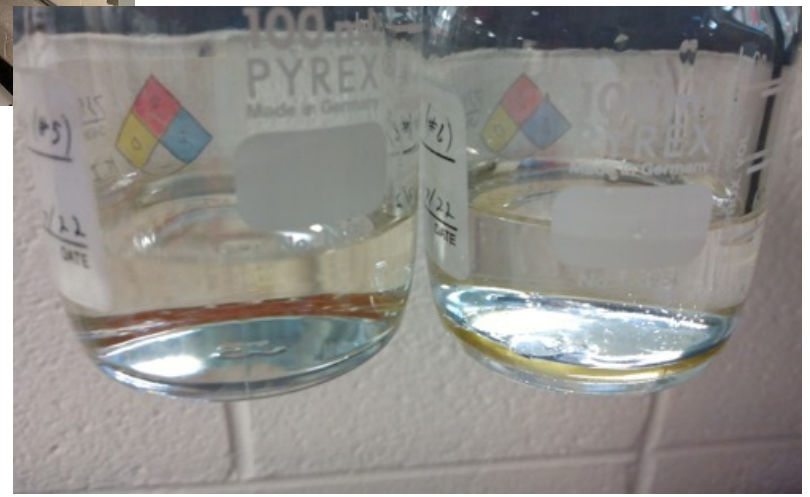
Goal: Hydrotreat/distill FCC product to jet fuel meeting ASTM specifications.

Accomplishments

- Hydrotreated FCC product from co-processing of 20% FT Wax with VGO and FCC product from VGO only.
- Both jet-fuel range cuts met the required specifications.

Continuous Hydrotreating Facility at NREL

Hydrotreated FCC products



Jet Fuel from Co-processing of FT Wax

Test method	Test quantity	Measured value	Allowable range
ASTM D4529	LHV	43.25 MJ/kg	min. 42.8 MJ/kg
ASTM D5972	Freezing point	-64.3°C	max. -47°C
ICP-OES	Sulfur content	<0.0015%	max. 0.3000%
ASTM D1298	Density at 15°C	0.824 kg/L	0.775 - 0.840 kg/L
ASTM-2887	Boiling range	meets spec.	upper and lower bounds

3. Impact

Outcomes will contribute to innovation and technology advancement including:

1) Comparing the performance of two approaches to biogenic intermediate production:
   a. Fixed-bed low-temperature FT synthesis, Co-based catalyst
   b. Slurry-bed low-temperature FT synthesis, Co-based catalyst
2) Developing a quantitative assessment of the fate of biogenic carbon in FCC co-processing
   a. Biogenic carbon in fuel-range products
   b. Biogenic caron in coke-on-catalyst
   c. Biogenic carbon in light gases and carbon oxides
3) Developing process conditions in commercial FCC to maximize diesel fuel range materials
   a. Temperature
   b. Reactor space time
4) Providing an industrial end-use for new biogenic feedstocks coming to the market soon and facilitating an understanding of the carbon intensity of fuels from co-processing
5) Developing an understanding of the chemistry and mechanisms for co-processing of fossil and biogenic materials in the FCC

3 – Impact Commercialization Potential of Distributed Biomass to FT Intermediate Facilities

- Biomass Availability
  - Forest Residual Biomass — 154 million dry tons/yr — ~7 billion gal/yr
  - Agricultural Residue Biomass — 72 million dry tons/yr — ~3.3 billon gal/yr

Combined over 10.3 billion gal/yr of potential liquid biofuels.

- 100 MWth Commercial Facility
  - Feedstock: Lignocellulosic (forest waste, agricultural residues)
    - 155,125 dry tons/per year of feedstock is estimated to produce
      ~3.5 million gal/yr (as direct FT diesel from Fischer Tropsch synthesis)
      ~3.5 million gal/yr (from FT wax for upgrading via refinery co-processing)

Annual production of 7 million gal/yr per facility of FT intermediates for liquid biofuels production

From: 2016 billion ton study

Summary

- Project integrates process to convert forest and agricultural biomass into FT diesel and FT wax intermediate for processing in a refinery to additional diesel fuel
- Biomass-derived intermediate can be co-processed using standard refinery equipment to introduce renewable carbon into the existing fuels infrastructure
- First project to investigate FCC co-processing of FT product with VGO providing data on a viable near-term pathway for diesel fuel with significant biogenic content
- Full commercialization of this technology will:
  - Utilize infrastructure at refineries to produce drop-in renewable diesel fuel
  - Reduce climate emissions, wildfire and open burning
  - Increase fire mitigation, jobs, energy security and flexibility
- All equipment has been installed and the project will begin testing this year

Agricultural and Woody Biomass to Diesel Fuel with Intermediate

Timeline

- Project start date: April 2021
- Project end date: December 2025

	BP 2 Apr 2022 – Dec 2023	Active Project
DOE Funding	$1,081,548	$2,200,000
Project Cost Share	$655,000+	$733,000+

Project Lead:

WestBiofuels

Project Partners:

NREL National Renewable Energy Laboratory

BEST Bioenergy and Sustainable Technologies

University of California San Diego

Project Goal

Demonstrate the production of a biomass-derived intermediate for co-processing in conventional refinery equipment to facilitate the introduction of renewable carbon into the existing fuels infrastructure

End of Project Milestone

A full process pilot demonstration to generate intermediate product to produce at least 100 gallons of drop-in diesel fuel in the total intermediate and co-processing products

Funding Mechanism

DE-FOA-0001926: Process Development for Advanced Biofuels and Biopower

Topic Area 2: Drop-in Renewable Diesel Fuel Blendstocks. Year: 2018

TRL at Project Start: 5

TRL at Project End: 7

Questions and Discussion

Matthew D. Summers, PI
matt.summers@westbiofuels.com

An Nguyen, Project Manager
an.nguyen@westbiofuels.com

WEST BIOFUELS, LLC
14958 County Road 100B
Woodland, CA 95776
530-207-5996