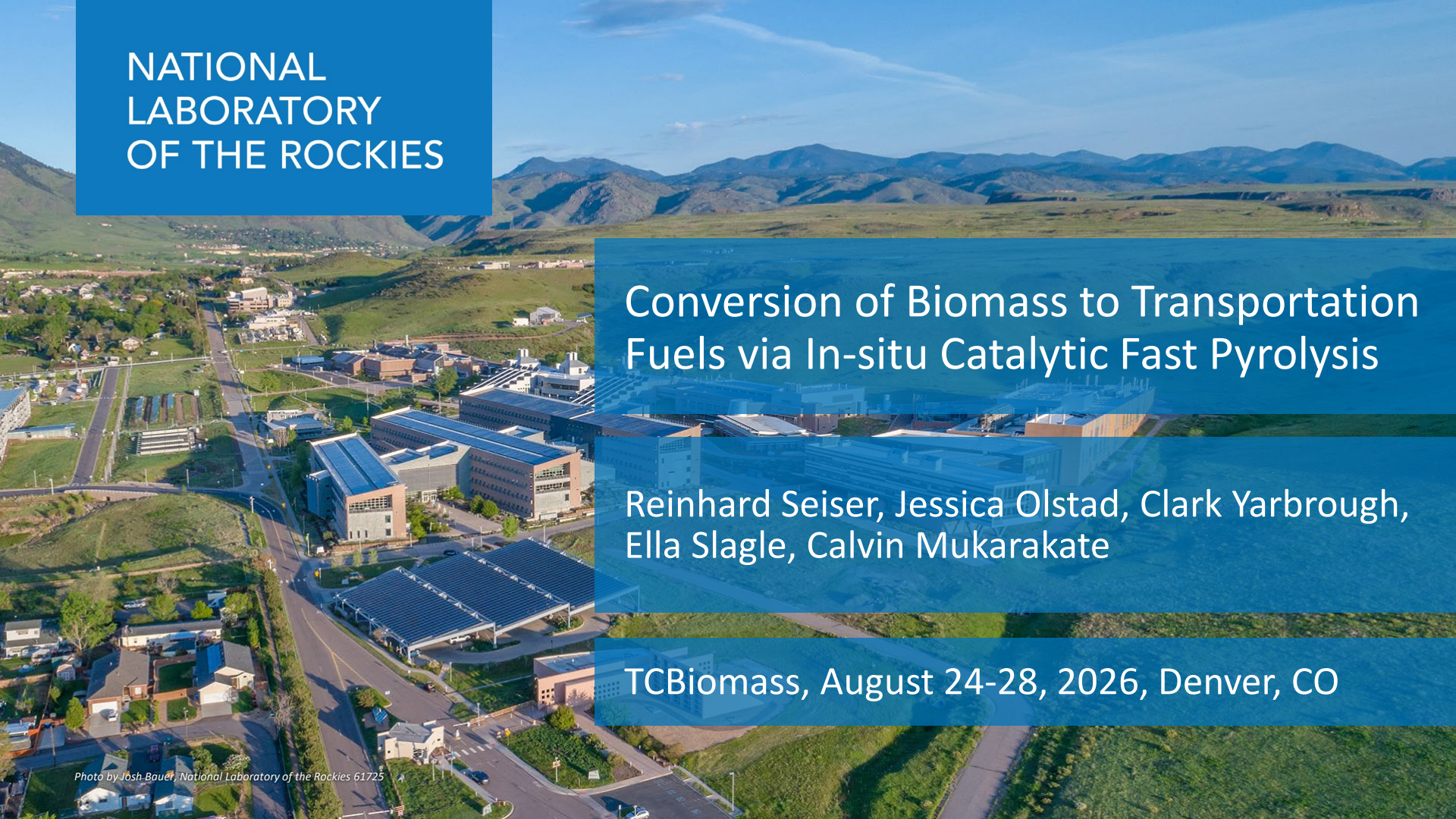




NATIONAL
LABORATORY
OF THE ROCKIES

Conversion of Biomass to Transportation Fuels via In-situ Catalytic Fast Pyrolysis

Reinhard Seiser, Jessica Olstad, Clark Yarbrough,
Ella Slagle, Calvin Mukarakate

TCBiomass, August 24-28, 2026, Denver, CO

Introduction

Goal: produce liquid intermediates from biomass for refinery integration

- CFP Oil is a possible candidate for co-processing.
- While not miscible with VGO, good deoxygenation, yields and biocarbon incorporation were previously obtained in FCC experiments.
- Compared with FP Oil, CFP Oil contains less oxygen, less water, and has better storage/transport properties.

Abbreviations:

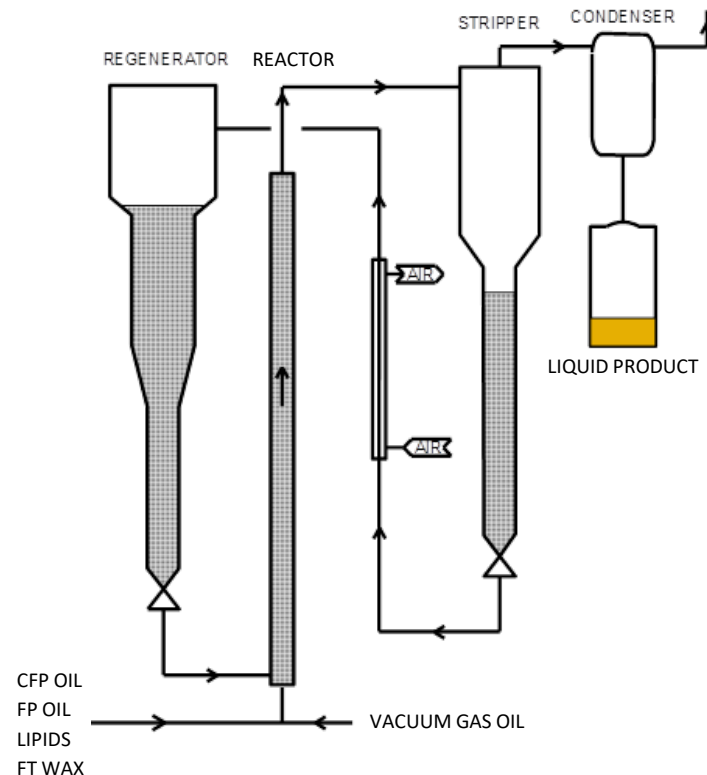
FP Oil (Fast Pyrolysis Oil)

CFP Oil (Catalytic Fast Pyrolysis Oil)

Lipids (Vegetable Oils, Tallow)

FT Wax (Fischer Tropsch Wax)

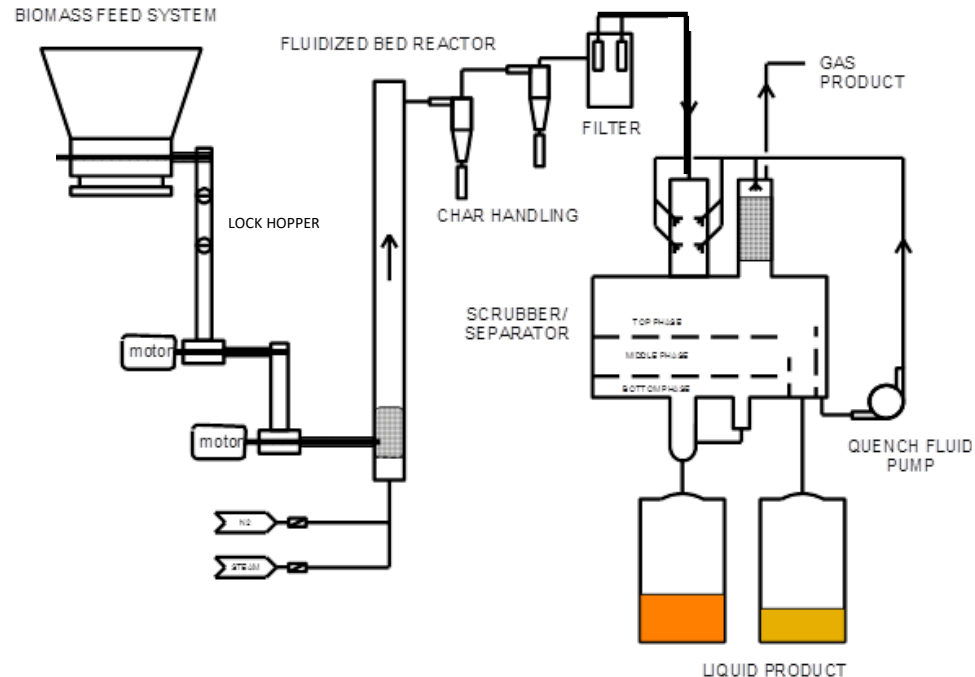
Laboratory FCC Unit (Fluid Catalytic Cracking) DCR (Davison Circulating Riser)



In-Situ Catalytic Fast Pyrolysis

- Employ catalyst inside fluidized-bed pyrolyzer.
- Alumina provides alternative to zeolite catalysts.
- Sasol Inc provided theta alumina Puralox 300/130 (nominal diameter 300 μm , surface area 130 m^2/g).
- Initial tests in pilot-scale circulating bed reactor showed very low organic liquid yield. Suspected temperature or heating rate as causes.
- Experiments were repeated in laboratory pyrolyzer at NLR. Again, low liquid yields were observed.
- Both experiments used a liquid scrubbing system, and both showed low mass balance closure.

Laboratory Pyrolyzer at NLR

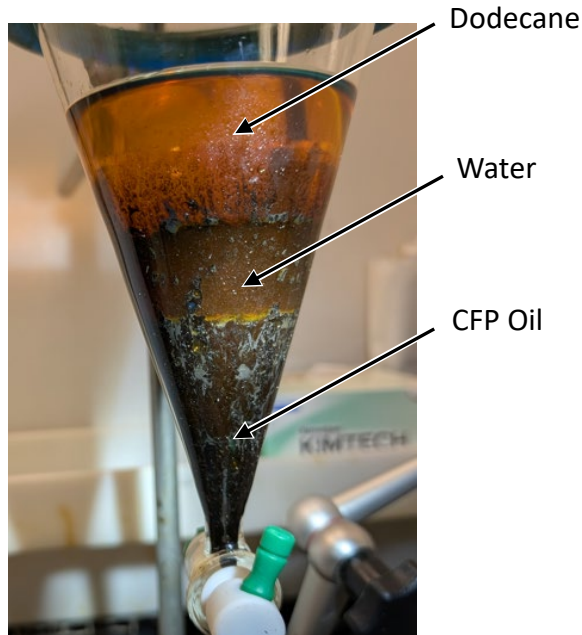


Influence of Dodecane and Water

Scrubbing fluid
(dodecane) after
several runs



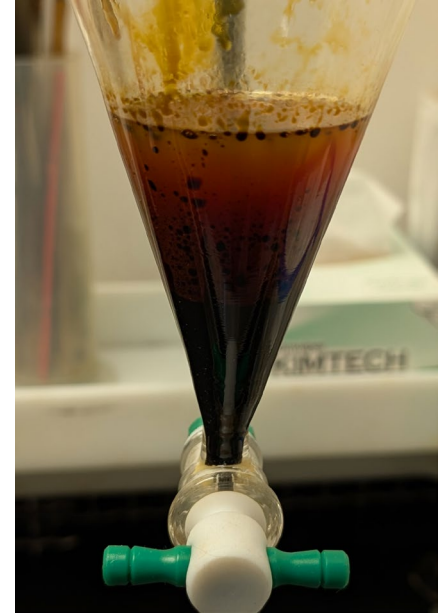
Typical product
retrieved from
scrubber



CFP oil after
mixing with
excess dodecane

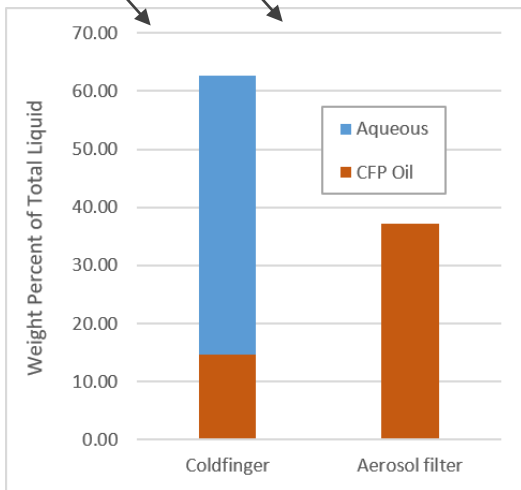
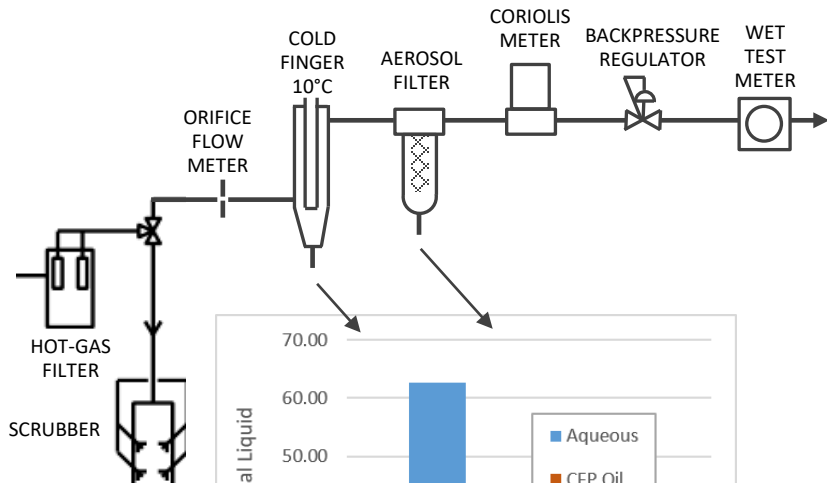


CFP oil after
mixing with
water



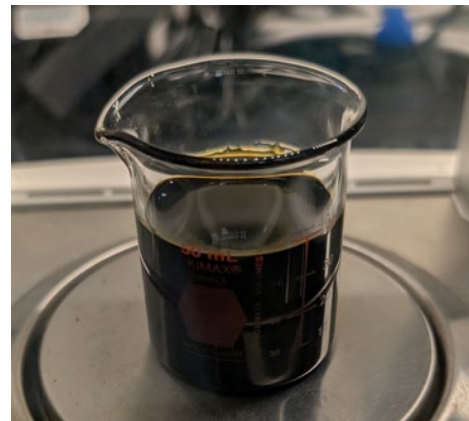
→ Large fractions of CFP oil are solubilized/suspended in water and dodecane, decreasing the quantity and quality of remaining organic phase

Condensing of Slipstream before Dodecane Scrubber



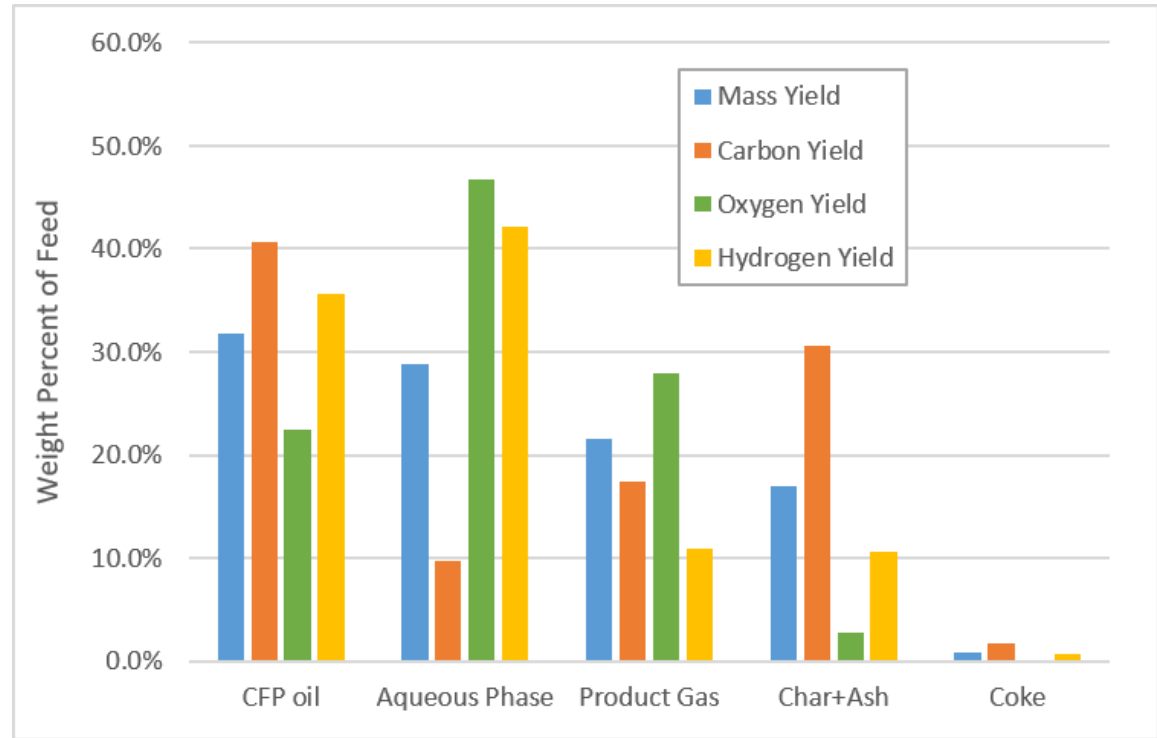
		Coldfinger	Aerosol Filter	Combined
Moisture	[w%]	12.3	8.3	9.4
O content	[w% dry basis]	19.4	28.7	26.2

Combined CFP Oils from Both Condensers



Experimental Data and Yields

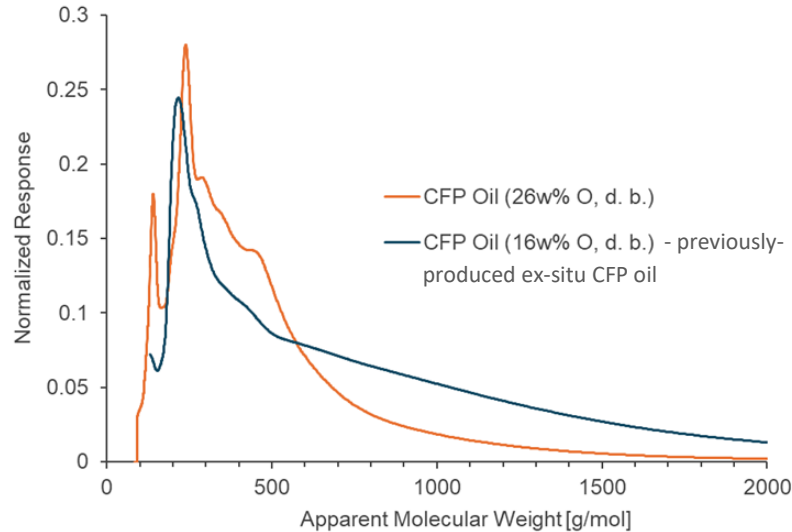
- Fluidized-bed reactor with theta-alumina catalyst (SASOL Puralox 300/130)
- Temperature 470°C
- Pressure 32 psia (2.2 bar)
- Feedstock is clean pine, knife-milled to 1 mm
- Feed rate is 1.3 kg/h
- Slipstream is 23% of total



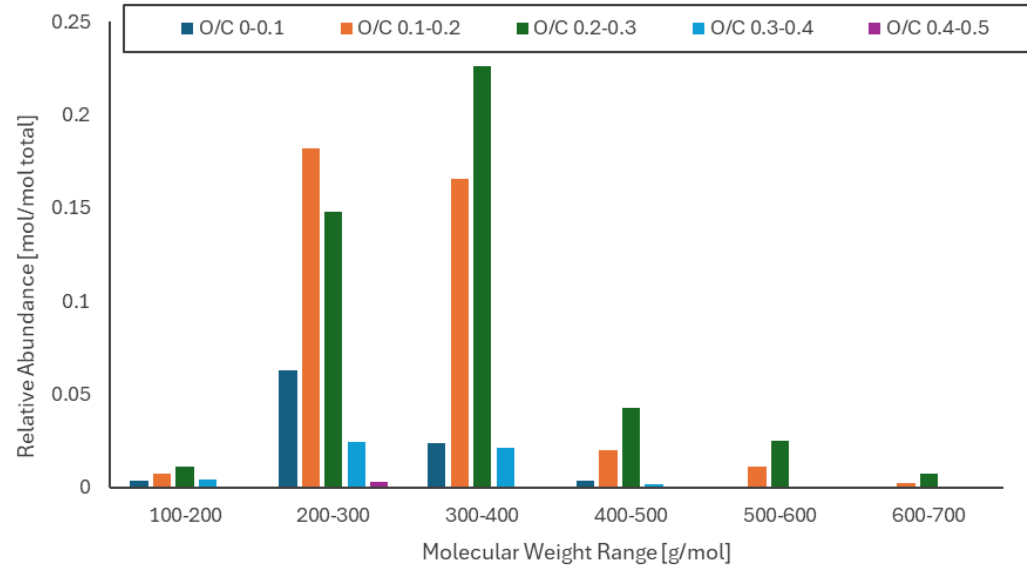
Product Gas Composition (mol%, N₂-free): CO: 50%, CO₂: 33%, H₂: 4%, CH₄: 10%

Analysis of CFP Oils

Gel Permeation Chromatography



FT-ICR-MS (Fourier-Transform Ion Cyclotron Resonance Mass Spectrometry)



Other Analysis Methods

GC-MS showed phenols, carbonyls, furans, anhydro-sugars, and acids.

^{13}C NMR for C=O, aromatic C-O/C-C/C-H, aliphatic C-O/C-C, and methoxy bonds

GCxGC for identification of phenolics, carbonyls, indeones, and levoglucosan (using larger columns)

FT-ICR-MS Molecular Formulas

Example: Molecular Weight Range of 300-305 g/mol

C	H	O	Rel. Abundance in MW Range	MW
18	21	4	15.48%	301
18*	21	4	2.48%	302
17	17	5	11.66%	301
17*	17	5	2.19%	302
17	19	5	8.75%	303
17*	19	5	1.35%	304
18	23	4	7.51%	303
18*	23	4	1.61%	304
20	29	2	6.29%	301
20*	29	2	1.87%	302
19	25	3	5.03%	301
19*	25	3	1.21%	302

*includes one ^{13}C atom

No molecules with N or S observed. Most molecules contain 4-5 O atoms. H/C ratios indicate aromatics.

Hydrotreating of CFP Oil

NLR's Continuous Hydrotreater

385°C and 1800 psi (124 bar)

Liquid flow rate of 2.5 ml/h, hydrogen flow rate of 10.5 NL/h

Sulfided NiMo catalyst from Johnson Matthey

Results showed 85% carbon yield to liquids, with boiling point ranges of naphtha (37 w%), jet fuel (53 w%), and diesel (10 w%)



Overall Process of CFP + Hydrotreating

CFP Oil



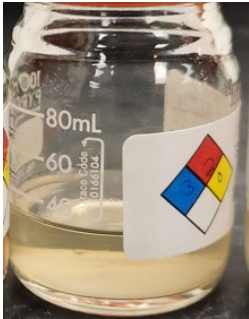
Aqu. Phase



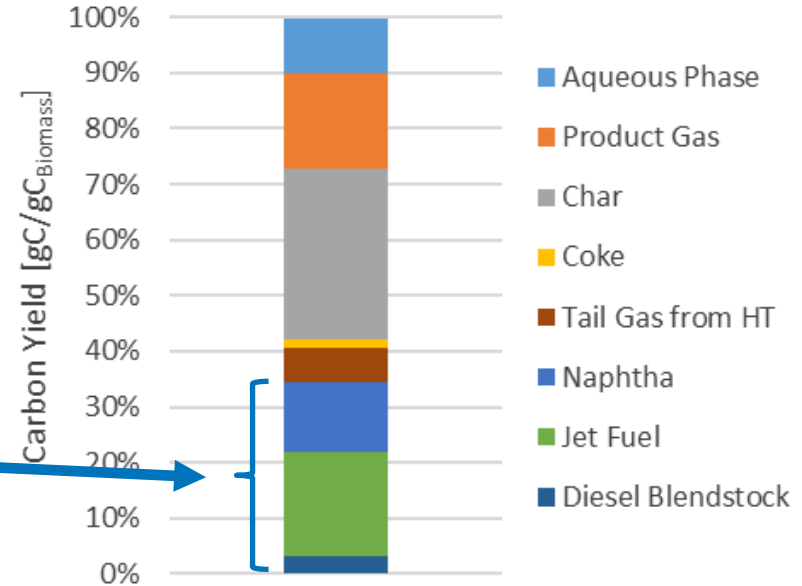
Char



Hydrotreated



Projected Overall Carbon Yield



Conclusions

- *In-situ* CFP using theta alumina provides liquid yields in line with other CFP techniques.
- Hydrotreated product fractions fall into the jet fuel, naphtha, and diesel range.
- Future work to address the following:
 - Test other feedstocks, such as alkali-containing ag wastes
 - Investigate stability of hydrotreating, impacted by aldehydes
 - For fuel production, consider catalyst modifications to improve de-oxygenation chemistry
 - For chemicals production, consider oxygenates for phenols, carboxylic acids, or ketones

Acknowledgments

Other Co-workers

- Kristiina Iisa
- Kellene Orton
- Steven Rowland
- Cheyenne Paeper
- Guy Winters

DOE Funding

- Grant DE-EE0008510
- Agreement NL/DE-EE0037481, 37482

This work was authored by the National Laboratory of the Rockies for the U.S. Department of Energy (DOE), operated under Contract No. DE-AC36-08GO28308. Funding provided by Office of Energy Efficiency and Renewable Energy. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.



Photo: FTLB Pyrolyzer and DCR

Q&A

www.nlr.gov

NATIONAL
LABORATORY
OF THE ROCKIES

Additional Slides

Potential Two-Stage Catalytic Fast Pyrolysis in DCR

Pyrolyzer using In-Situ Catalyst

Circulating Bed Reactor for Pyrolysis Vapor Upgrading

Similar work by Valmet,
Johnson Matthey

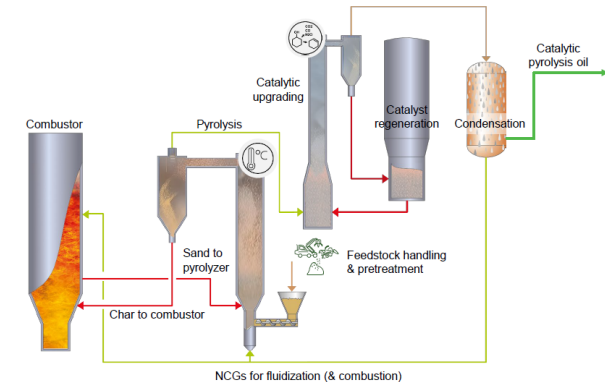
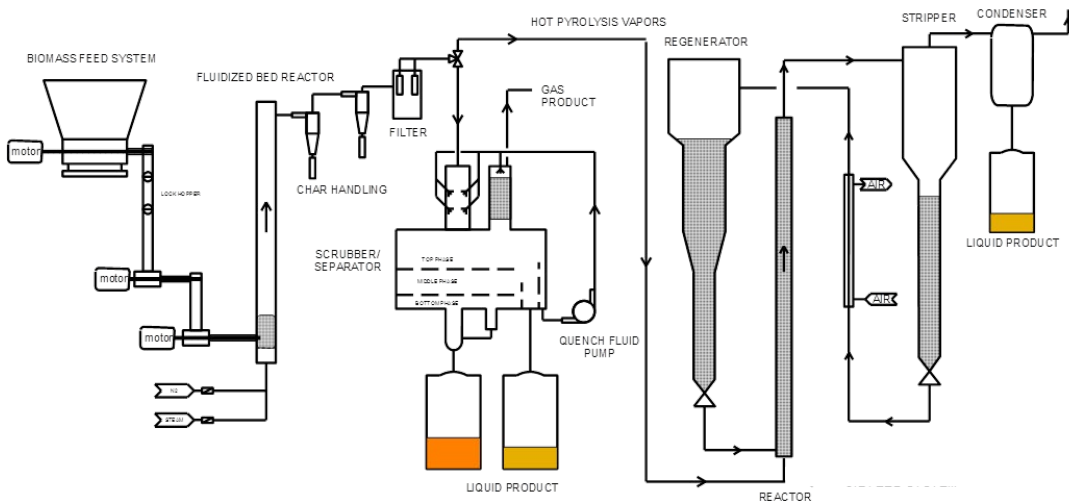


Photo Credit: Valmet

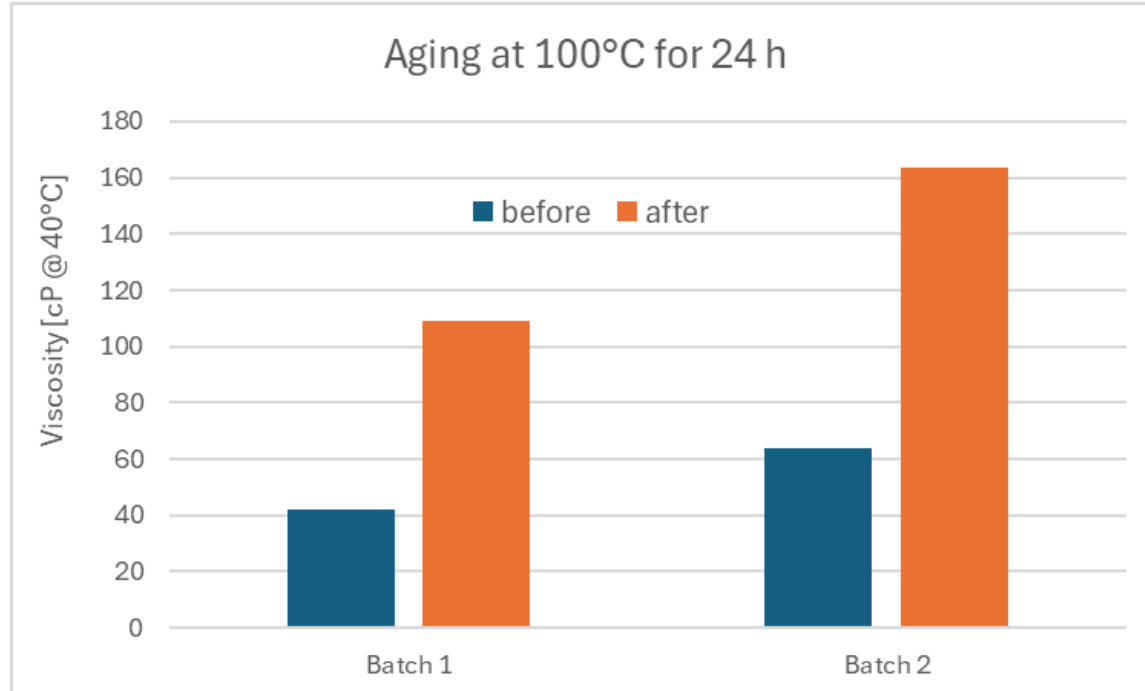
Stage 1:

- Catalyst alkali tolerant
- CFP vapors not blinding hot-gas filter
- Co-pyrolysis of plastics or tail-gas

Stage 2:

- Riser providing ideal environment for producing intermediates.
- Zeolite-based or other catalysts
- Previous test showed tradeoff between de-oxygenation and yield.

Additional CFP Oil Properties



Additional CFP Oil Properties

